

THE ASEPTIC TREATMENT OF WOUNDS

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*Gratefully dedicated to
the Peter Bent Brigham Hospital,
an environment in which the opportunity
and responsibility essential for early
professional maturity abound*

PREFACE

ne prompt, kindly healing of wounds, g a rarely attained goal of the most adept con, has become so routine that modern g ons habitually assume the miracle of 1870's to be an attribute of their own rather than a specific system of treatment as effective and spectacular as that of chemotherapy. Indeed, a wave of chemocutic hysteria has engulfed many surgeons, whose aseptic treatment is unknowingly so sketchy that wound complications mar their work.

The aseptic treatment of the wound in the operating room is the culmination of much daily thought and effort on the part of those to whom the responsibility for details has been relegated; that most surgeons think of asepsis only as the use of rubber gloves and a few sterile drapes is only too true. Even the host of laymen who contribute to asepsis influence the sterility of the operative field more often than does the surgeon.

This monograph is an attempt to correlate the knowledge and effort of all who contribute toward the aseptic treatment of wounds, much as did Curt Schimmelbusch's monograph of similar title fifty years ago. While it was written primarily to serve as a text for medical school courses in surgical technic, it is hoped that it will enable manufacturers, salesmen, architects, trustees, administrators, contractors, and craftsmen, such as plumbers, steamfitters, or electricians,

to orient their contribution to the care of the patient and make them realize their grave responsibility for his safety.

The scientific data presented may prompt nurses and surgeons to question the wisdom of pride in a traditional technic and continued subservience to expediency. Failure to standardize aseptic technic on a scientific basis is in itself an outstanding fault, because the successful performance of any technic depends upon the respect and cooperation it commands from all concerned with its proper function. Every change in personnel, whether among surgeons, nurses, medical students or lesser subordinates, introduces uncertainty in the chain of safety until the newcomer forgets previous training, which may well have been superior, and learns a new brand of "asepsis." Carelessness, tradition, expediency, and habit dictate many technics, whereas safety for the individual patient demands a basis of fact and a standardized technic.

The technic described, one of several acceptable technics, is that elaborated at the Peter Bent Brigham Hospital and expresses the surgical philosophy of Harvey Cushing and Elliott C. Cutler. Many surgeons and nurses have contributed ideas and constructive criticism and, above all, were tolerant and understanding when it seemed easier to do things "the old way." The author was fortunate in working with Catherine Richards, Esther Kinney, Bridget

Egan, and Elizabeth Comusky, successive operating room supervisors, each of whom aided in improvement of technic during the past twelve years

The myriads of questions prompted in the minds of medical students, internes, and nurses by the inconsistencies and discrepancies in aseptic technic established the need for this book. Numerous adventures in hospitals where postoperative infection and sepsis presented problems broadened its scope. Even within one hundred miles of Boston, hospitals were visited where instruments were not sterilized routinely between cases, where the chamber of a steam sterilizer had never been connected to the steam supply, where waterproof duck was used as sterilizing wrappers, where the dry goods frequently burst into flame as they were withdrawn from the sterilizer, where the superintendent's hero was an orderly who "sterilized" twice as much dry goods in half the time usually needed by the nurses by simply pushing the packages through a double ended autoclave into the "sterile" supply room. In each instance, surgeons requested help to solve problems that basic knowledge would have avoided

Authorities in the surgical trade often proved to be the ultimate source of knowledge and the principal sterilizer manufacturers have put their facilities at the author's disposal

Special mention must be made of the assistance of Adolph Watzka who has made a noteworthy career of enforcing aseptic technic, as can be attested by the thousands of patients he has lifted to the operating

table and the hundreds of students and young surgeons whose technic bears the imprint of his corrections

The bibliography is not exhaustive. Only thousands of references, only those of significance for the student interested in more detailed knowledge are listed

The illustrations, particularly the graphs and diagrams, are shown with sufficient poetic license to emphasize the basic principles involved rather than to represent the actual data. The latter can readily be obtained by referring to the original work for which references are given.

The diagrams which clarify technical points were produced in collaboration with draftsmen of the Wilmot Castle Company, Rochester, New York

So much of the book is carried by the illustrations that Miss Mildred Coddington has played the role of co-author rather than artist. The author is grateful not only for her skill but also for the loyalty and persistence with which she carried on for six months while he was convalescent.

The industry and devotion of Miss Dorothy Wysocki are responsible for the preparation of the manuscript, lettering of the graphs and diagrams, and building of the index.

The manuscript was reviewed by Dr. S. Burt Wolbach. His suggestions and criticisms were appreciated greatly.

Finally, the author acknowledges the stimulus and inspiration of Dr. Elliott C. Cutler whose zeal bridged the North Atlantic to good publication.

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CHAPTER I

THE IMPORTANCE OF THE ASEPTIC TREATMENT OF WOUNDS

— CURT SCHIMMELBUSCH, 1893 *

"It is well for us, who have profited by the achievements of our predecessors, and who watch the progress of science perhaps not without occasional misgivings, to look back upon the past and gauge the value of what we have inherited. We need not go back to ancient times, in which the performances of surgery were cramped by want of anatomical and physiological knowledge, no less than by imperfect technique, we need go no further back than thirty or forty years. Let us compare the modern epoch of our science with that period, in which the highest abilities and a degree of operative skill, that we cannot hope to surpass, were powerless to control the dark issues of the fate that hovered over the wounded, making all calculations of the results of operations futile. At that time, the idea of a wound was inseparable from that of fever, the healing of a wound without inflammation was not known, and wound fever and wound inflammation appeared to be the normal reaction of the injured organism. It was then that Pirogoff wrote his treatise on luck in surgery, in which, after long years of surgical practice, he so resignedly gave expression to the feeling of the futility of his own skill, and estimated the influence of

the surgeon, of the method of treatment, and of mechanical dexterity, at nothing compared with that of chance in determining the success of an operation. Suppuration, purulent edema, hospital gangrene, erysipelas, and traumatic tetanus, the scourges of surgery, as Pirogoff¹ aptly terms them, dogged the steps of the surgeon and frustrated his success.

"Landpaintner² writes of Nussbaum's Clinic in Munich as follows: 'Eighty per cent of all wounds were attacked by hospital gangrene. Erysipelas was so much in the order of events, that its occurrence could almost be regarded as normal, it was a standing axiom to sew up no scalp wound, healing by primary intention was practically unknown, and suturing had at most the result of favouring by retention of secretion, the occurrence of erysipelas. In one year 11 out of 17 amputations died of pyaemia alone, in our department a compound fracture was very rarely to be seen, for either the limb was amputated at once, or the occurrence, in a few days' time, of purulent infection, hospital gangrene, and septicaemia rapidly led to a fatal result.' The mortality after compound fracture, in Volkmann's Clinic at Halle, had been 40

* SCHIMMELBUSCH, CURT. *The Aseptic Treatment of Wounds*. Berlin, 1893. Chapter I translated by Alfred T. Rake, 1894. H. K. Lewis and Company Ltd.

¹ PIROGOFF. *N. Klin. Chir.*, Leipzig, 1854.

² LANDPAINTER. *J. Ergebnisse der Lister'schen Wundbehandlung, Deutsche Zeitsch. f. Chir.* 7:187 1877.

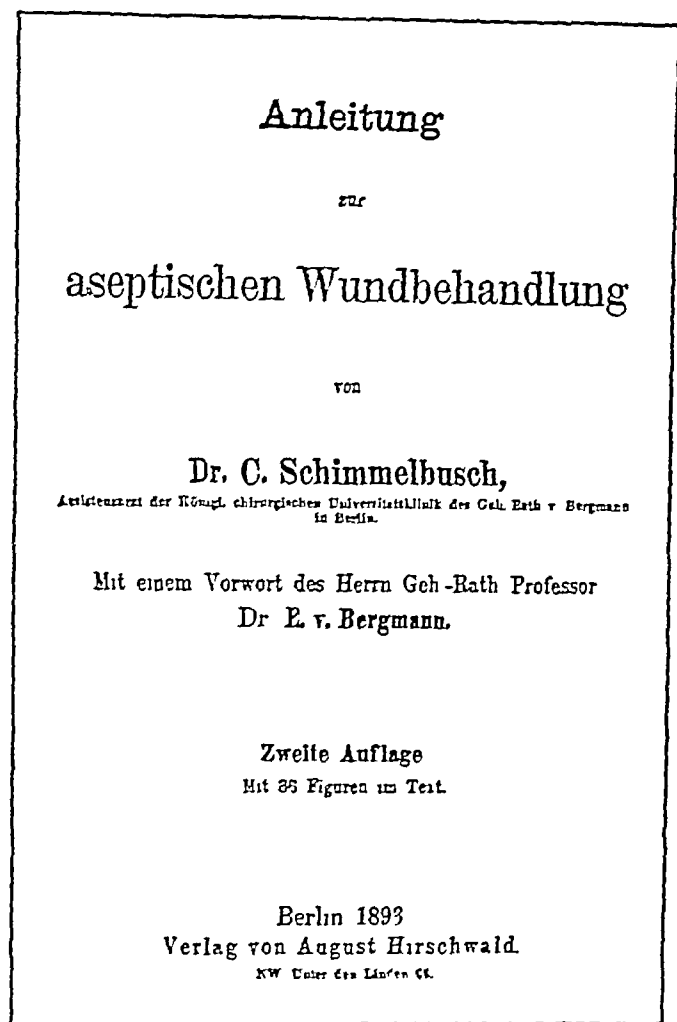


FIGURE 1

Facsimile of the title page of *The Aseptic Treatment of Wounds* by Curt Schimmelbusch, Berlin, 1893

per cent during the long period of his predecessor's rule as well as during his own, and in the years 1871 and 1872 the number of the victims claimed by pyaemia and erysipelas was so large, that Volkmann entertained the idea of closing his Clinic for a time.

"How different is all this at the present time! The Clinics, in which twenty years ago hospital gangrene was reckoned the most frequent disease of wounds, are now-a-days in such a condition, that the medical student no longer has the opportunity of seeing hospital gangrene, and most young surgeons no longer recognise the disease. The most serious operations under modern

surgeons run a favourable course with such a certainty, that the chance of a failure in the healing hardly enters into their calculations. Fatal inflammation after amputation should, as a rule, no longer occur

"There is now no such thing as good and bad luck in the treatment of a wound, the fate of the patient lies in the hands of the surgeon who performs the operation and dresses the wound. The old saying of Ambrose Paré, '*Je le pansays, Dieu le guarit,*' has ceased to be the involuntary motto on the shield of the operating surgeon, and in putting on the dressing, the surgeon undertakes the entire responsibility for complete and certain healing. 'A short time ago,' says Volkmann³ in his excellent way of expressing it, 'the surgeon when he had completed a bloody operation, according to rule, was like a husbandman, who having sown his field, waits with resignation for what the harvest may bring, and reaps it, fully conscious of his own impotence against the elemental powers, which may pour down on him rain, hurricane, and hail-storm. Now he is a craftsman from whom one expects good workmanship'

"In the duration of the processes of healing, modern surgery has been revolutionized. In 1875 Nussbaum⁴ complains that accident cases from the working classes were only provided, according to contract, for nine weeks in hospital, and adds that for many this limit was not sufficient, that even in the case of quite insignificant wounds, healing was not complete till much later, owing to inflammation. The healing of an amputation of the breast usually took from three to six months, the healing of the major amputations often several months

³ VON VOLKMANN, R. Ueber den antiseptischen Oclusivverband, &c., die Behandlung der complicierten Fracturen, die moderne Chirurgie, *Samml. Klin. Vorträge — Chirurgie*, 30

⁴ NUSSBAUM, J. N. *Lister's grosse Erfindung*, ein klinischer Vortrag, München, 1875

Now we see amputations of the breast, with clearing out of the axilla, get well in a fortnight, and complain, if in a case of amputation of the thigh we have to keep the patient in the hospital over the third week, in order to have the artificial limb adapted. Our ideas are entirely changed. We no longer believe that the healing of a fresh wound must be different in the case of a cancerous or tuberculous patient from what it is in a sound one. The spectre of diathesis to wound inflammation has disappeared. We operate, with the assurance of uninterrupted healing, on the youngest and oldest no less than on the fully developed adult. The modern surgeon no longer anxiously avoids injury to the joints and body cavities, but without hesitation opens the abdomen or the skull, and touches organs which to the ancients were a *noli me tangere*.

"For this entire transformation in our art of healing, we have to thank the great discoveries, which at one stroke have dispersed the darkness which has hung for thousands of years over the infection of wounds. These discoveries have shown us that, like putrefaction and fermentation, wound infection depends upon minute organisms, and that it is only necessary to prevent their access in order to do away with the infection of a wound.

"And although the weapons, which we to-day use against the now recognised foe, are no longer those which were first chosen, and although yet better be discovered in the future, our gratitude will always remain the same to him who first showed us the path along which we progress, and the name of Lister will always be illuminated with the brightest light."

CHAPTER II

THE DEVELOPMENT OF THE CONCEPT OF ASEPSIS

For this disease seized such women only, as were visited, or delivered by a practitioner, or taken care of by a nurse, who had previously attended patients affected with the disease

In short, I had evident proofs of its infectious nature and that the infection was as readily communicated as that of the small pox, or measles, and operated more speedily than any other infection with which I am acquainted

— ALEXANDER GORDON, 1795 ¹

Many of the daily problems in aseptic technic, particularly those raised by inconsistencies and discrepancies in methods advocated by various surgeons, are easily understood and evaluated when analyzed from the perspective that the history of asepsis affords, figure 2. Many records give the retrospective impression that the author recognized that communicable disease can be controlled or that postoperative suppuration can be prevented. At best, they were but sporadic expressions of empiric thought and did not exert lasting influence. William Henry,² for example, described the hot air sterilizer in 1832, figure 3, as a means of destroying the contagious matter of scarlatina. Dry heat (stoving), however, was used only sporadically until bacteriologic study established its worth in 1881. During the period when the concept of controlling communicable disease was elaborated and aseptic technic was evolved, a thousand odd contributions to the literature built the tradition upon which modern technic

stands. Half of these concerned aseptic technic. The various brands of asepsis practiced today represent branches of the main stem which has outstripped them. Forty-two references of those listed in the bibliography represent only the technical headlines in a movement which covered roughly the nineteenth century.

The evolution of operative obstetrics was responsible for a chain of contributions on the etiology of puerperal fever which led to the establishment of the idea that communicable disease can be checked by rigid control of the channels which are responsible for its spread. Puerperal fever was a rarity until obstetrical operations fanned it to epidemic proportions and presented the profession with the grave problem of controlling a "professional pestilence" ³

Charles White of Manchester, England, the "Man Mid-wife Extraordinary to the Manchester Lying-in Hospital and Charity for Delivering Poor Married Women at Their Own Habitations," also a great surgeon and the principal founder of the Royal Infirmary of Manchester, spearheaded re-

¹ GORDON, ALEXANDER. *A Treatise on the Epidemic Puerperal Fever of Aberdeen*. London, 1795.

² HENRY, W. Further Experiments on the Disinfecting Powers of Increased Temperatures. *Philosoph Mag*, 11 22, 1832.

³ CUTTER, I. S. *History of Puerperal Fever, Obstetrics and Gynecology*. Philadelphia: W. B. Saunders Co., 1933, Vol. I, Chapter 2.

EVOLUTION OF ASEPSIS

KIRKLAND, THOMAS

1722

WHITE, CHARLES

1728

1773

Cleanliness and Isolation
checked spread of puerperal
fever

1813

1774

Puerperal fever not a spon-
taneously occurring disease

1798

GORDON, ALEXANDER

1752

1795

Puerperal fever a specific con-
tagion conveyed by doctor

1799

HENRY, WILLIAM

1775

1831

Invented a dry heat sterilizer
to check scarlatina

1836

FIGURE 2

EVOLUTION OF ASEPSIS (*Continued*)

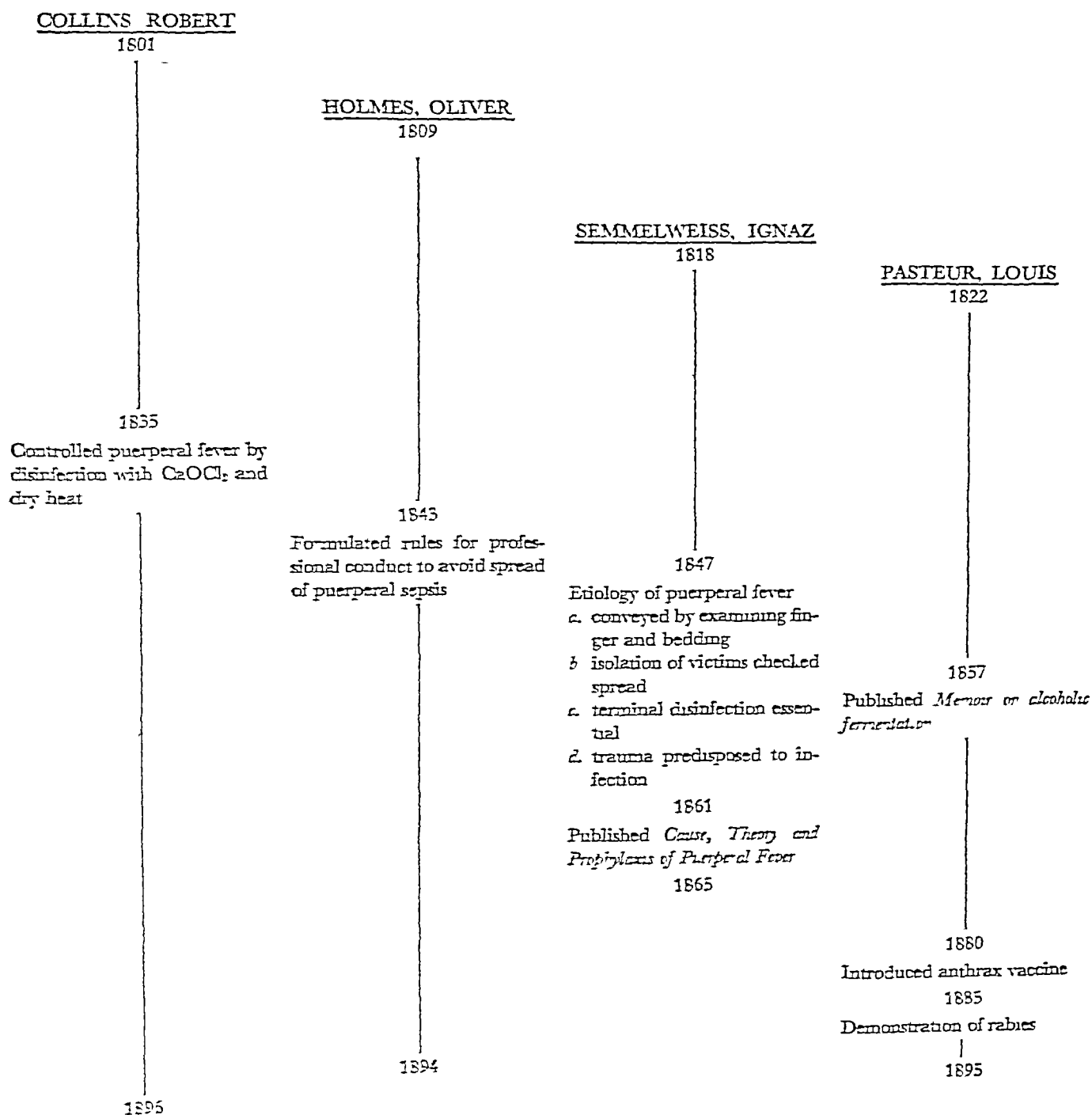


FIGURE 2

WELLS, SPENCER

1818

(Clinician influenced by Pasteur)

1858

"Absolutely Safe Ovariotomy" mortality was 34% by cleanliness and isolation, he reduced it to 11% by 1882

1897

LISTER, JOSEPH

1827

(Physiologist and surgeon influenced by Pasteur)

1867

Described exclusion of wounds in compound fractures and exclusion of air-borne bacteria with antiseptic dressings; advocated exclusion of bacteria from abscess cavities by antiseptic technique to permit healing without suppuration; antiseptics used to attain primary healing in elective surgery

1870

Attempted use of dry dressings sterilized by chlorine gas

1912

KOCH, ROBERT

1843

1876

Published *Transmission of Infectious Diseases*

1881

Antiseptics and sterilizers

1910

FIGURE 2

EVOLUTION OF ASEPSIS (*Continued*)

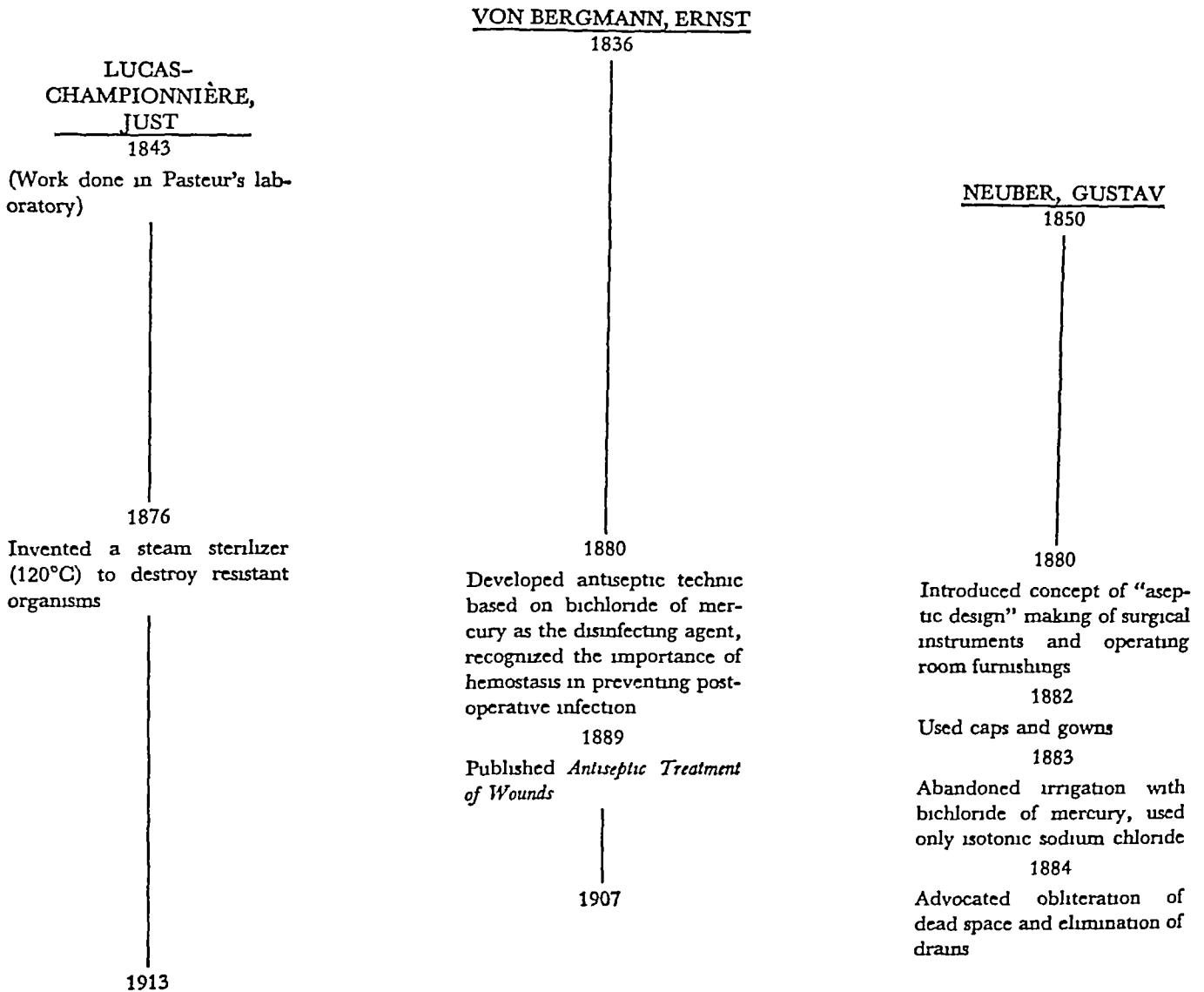


FIGURE 2

EVOLUTION OF ASEPSIS (Continued)

WOLFFHUGEL, GUSTAV

1845

(Work done in Koch's laboratory)

1881

Studied bacteriology of hot air sterilizer

1899

CAIRY, GEORG

1850

(Work done in Koch's laboratory)

1881

Invented a steam sterilizer and studied its bacteriology

1918

LOEFFLER, FRIEDRICH

1852

(Work done in Koch's laboratory)

1881

Invented a steam sterilizer and studied its bacteriology

1915

VON FISMARCH, ERVIN

1855

1884

Used dry sterile dressings for small wounds

1888

Studied effect of superheated steam in sterilizer; advocated routine bacteriologic proof of sterilization

1915

FIGURE 2

EVOLUTION OF ASEPSIS (Continued)

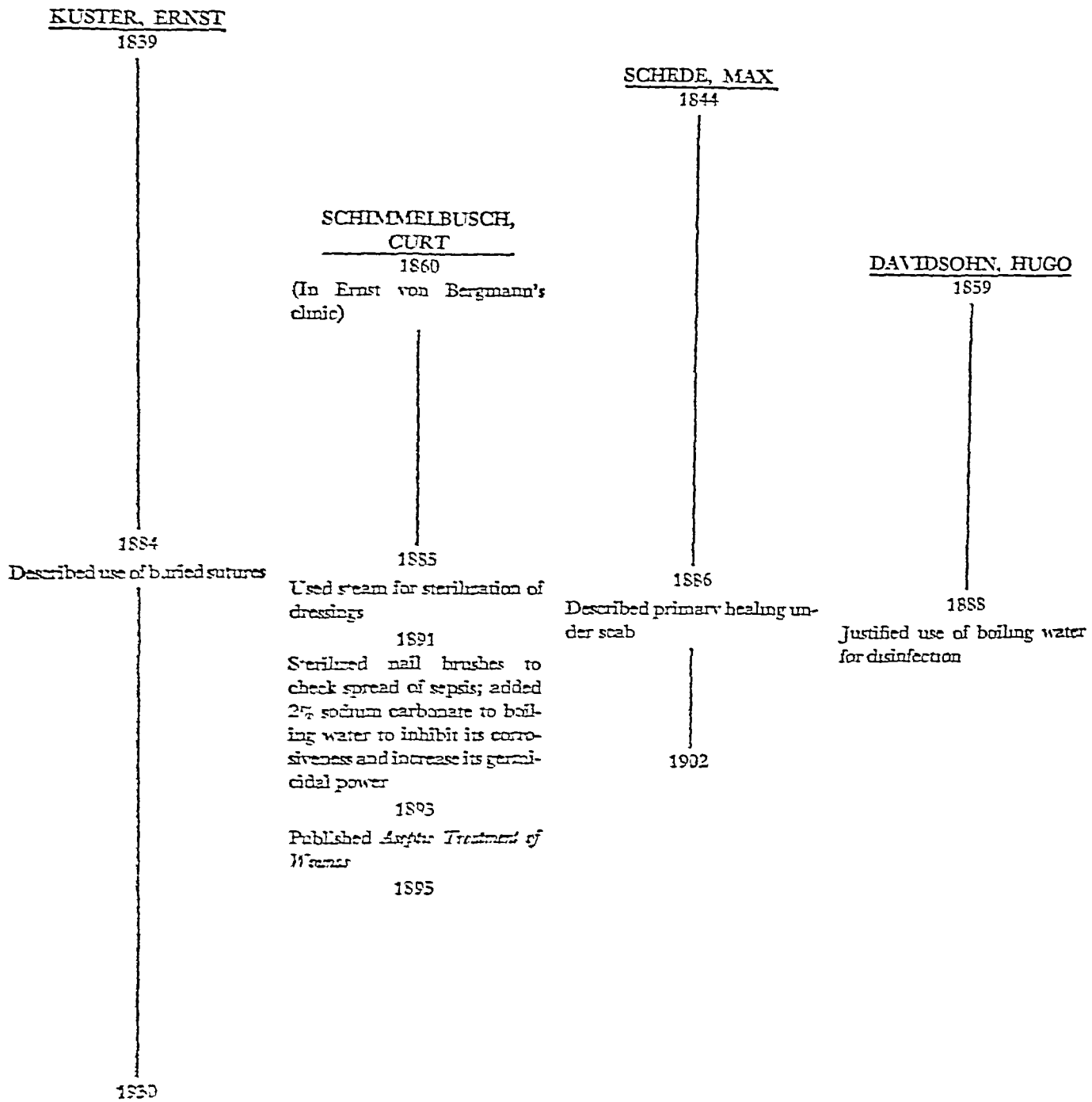


FIGURE 2

EVOLUTION OF ASEPSIS (Continued)

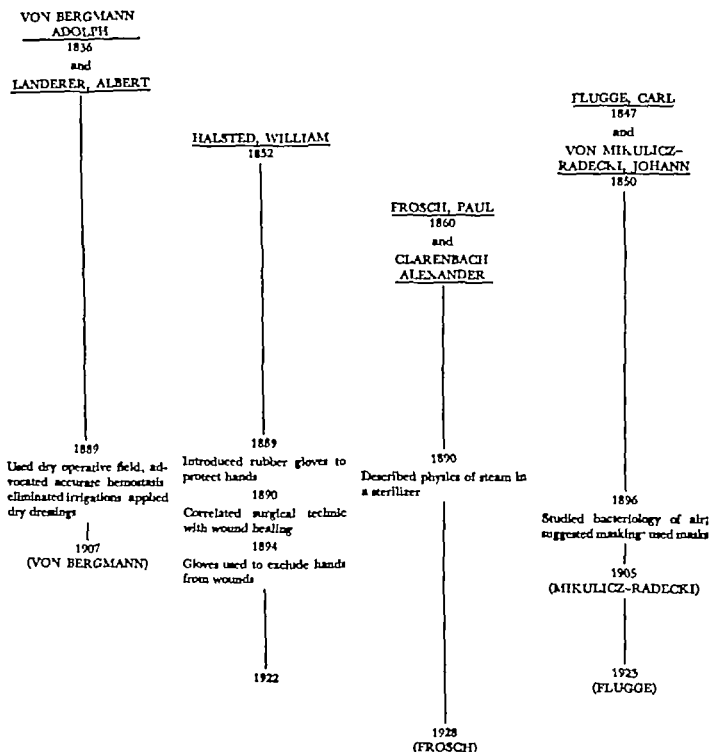


FIGURE 2

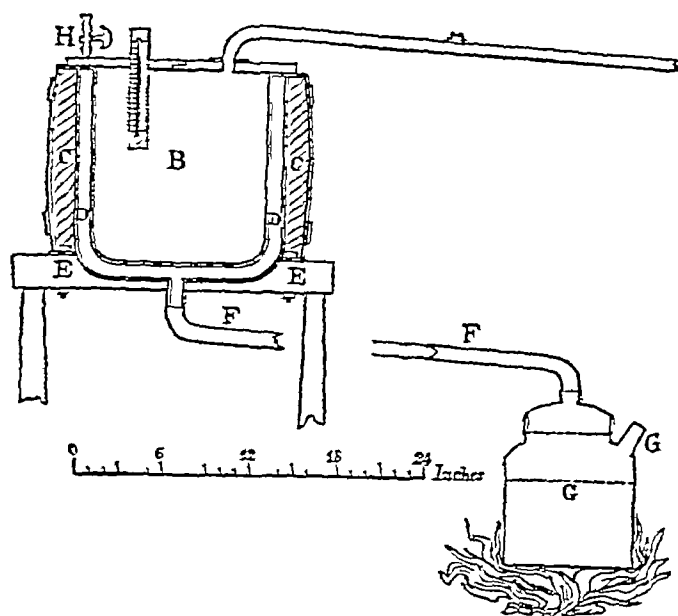


FIGURE 3

Diagram of a hot air sterilizer devised by William Henry in 1832 published in an article in *Philosophical Magazine* 11:22, 1832. The insulated C steam jacketed D disinfected chamber B was readily accessible by removing the loosely fitting lid. Steam from the boiler G was led to the jacket D to heat the wall of the disinfected chamber. The vent pipe A removed odors. The instructions were: "The vessel G is to be filled about two-thirds with water, which, to save time, may be nearly boiling at the outset. Being set over a fire, and the joints that require it having been made good by flour paste spread on paper, the opening G is to be shut by a cork or plug, and the small air-cock opened, to allow the escape of air confined in the space DD. Both halves of the cover being then put into their places, the thermometer is to be introduced through the slit. When it indicates upwards of 200°, that half of the cover from which the pipe A proceeds is to be removed, the infected articles are to be placed in the receptacle, and the half-cover replaced. The fire under the boiler is to be regulated, by the rate at which the excess of steam issues from the small air-cock.

"If thought expedient, a higher temperature than 212° Fahrenheit may easily be obtained in the receptacle, by subjecting the steam to a greater pressure than that of the atmosphere; the apparatus being in that case provided with a proper safety-valve."

form in obstetrical technic by his *Treatise on the Management of Pregnant and Lying-in Women*. He wrote that puerperal fever was due to putrefaction of lochia stagnating in the womb and termed it putrid fever (1773) because he thought it a systemic reaction, similar to surgical fever due to absorption

from abscesses and infected ulcers. He advocated postural drainage and quickly appreciated the value of Vaughan's bed, which was provided with a mechanically elevated backrest to support the patient in the sitting posture advocated years later by Fowler for the control of peritonitis. White introduced the dual concepts of cleanliness and isolation of the lying-in room, because he noted the higher incidence of fever among women in dirty and crowded hospitals. He was particularly emphatic regarding the isolation of those who had fever.⁴ His book was widely read and translated and provoked creative thought among his confrères.

A collaborator of White, Thomas Kirkland,⁵ described the uterus in puerperal fever as a septic wound from which toxic products that caused fever were absorbed. He was militant against the current opinion that puerperal fever was a spontaneously occurring disease.

There were many authors who confirmed the observations of White and Kirkland prior to the publication of Alexander Gordon's epidemiologic study of an outbreak of puerperal fever at Aberdeen in 1795, figure 4. He likened puerperal fever to erysipelas and clearly recognized that during erysipelas epidemics, hospitalized patients developed erysipelas in the vicinity of traumatic wounds shortly after admission and that postoperative wounds readily developed erysipelas.¹ Gordon described puerperal sepsis as a specific contagion implanted or conveyed by the practitioner or nurse who had previously attended infected patients. He found the disease easy to control by the simple procedure of washing the hands and donning clean clothes before examining the pregnant patient. Surpris-

⁴ WHITE, CHARLES. *A Treatise on the Management of Pregnant and Lying-in Women*. London, 1773.

⁵ KIRKLAND, THOMAS. *A Treatise on Child-bed Fevers and on the Methods of Preventing Them*. London, 1774.

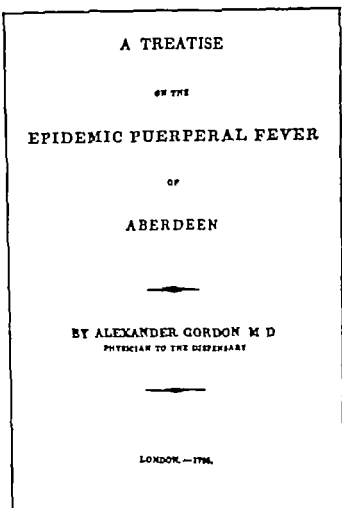


FIGURE 4

Facsimile of the title page of *A Treatise on the Epidemic Puerperal Fever of Aberdeen* by Alexander Gordon, London, 1795

ingly, these significant observations were accepted by but few and puerperal sepsis continued to be prevalent despite the writings of others who elaborated the original concepts of White and Gordon

The most outstanding demonstration of the ease with which the disease can be controlled was that of Robert Collins who disinfected the rooms of the Rotunda Hospital of Dublin with chlorine gas and subsequently practiced terminal disinfection of the quarters and furniture with "chloride of lime" (CaOCl_2) mixed with water. Blankets and the like were disinfected by

* COLLINS, ROBERT. *A Practical Treatise on Midwifery* London, 1835.

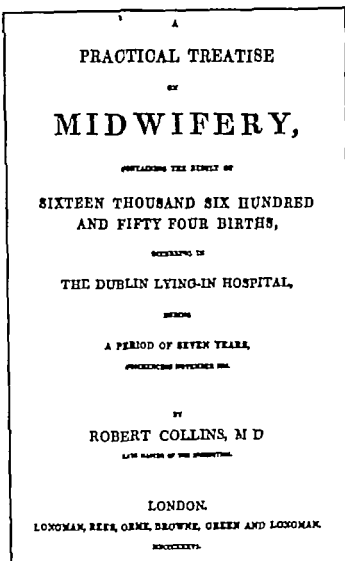


FIGURE 5

Facsimile of the title page of *A Practical Treatise on Midwifery* by Robert Collins, London, 1835

hot air. During the four years this routine was performed, not one patient of the 10,785 succumbed to infection, figure 5. The gross maternal mortality was but 0.53%. This demonstration was particularly significant because the Rotunda Hospital had long recognized the value of cleanliness in the suppression of the disease and also because a serious epidemic of puerperal fever broke out when the use of chlorine was abandoned by Collins' successor. Despite this striking demonstration, Collins' methods were not used elsewhere.

In 1843, Oliver Wendell Holmes became the articulate exponent of the theory of the

Die Aetologie, der Begriff
und
die Prophylaxis
des
Kindbettfiebers.

Von
Ignaz Philipp Semmelweis,
Dr. der Medizin und Chirurgie, Regierender der Geburtshilfe, u. a. Professor der theoretischen
und praktischen Geburtshilfe an der k.k. ung. Universitäts zu Pest
etc. etc.

Pest, Wien und Leipzig
C. A. Hartleben's Verlags-Expedition.
1861.

FIGURE 6

Facsimile of the title page of *The Etiology, Theory and Prophylaxis of Puerperal Fever* by Ignaz Semmelweis, Pest, 1861

contagiousness of puerperal sepsis and reiterated the idea that puerperal sepsis was a disease which followed the doctor around.⁷ He formulated logical rules for professional conduct and stimulated much discussion among American doctors which culminated in reform in technic.

The etiology of puerperal fever was finally established by Ignaz Semmelweis who had pondered the discrepancy between the incidence of sepsis on the wards in charge of midwives and those cared for by doctors and medical students, the latter

⁷ HOLMES, OLIVER W. Contagiousness of puerperal fever, *N.E.Q.J. Med. & Surg.*, 1:503, July, 1842

group in one year showed a mortality of 9.9% due to sepsis. While attending an autopsy on his colleague, Kolletschka, who died from sepsis following a wound inflicted while dissecting a cadaver, Semmelweis was struck by the similarity between the disease that had robbed him of a colleague and that which he had seen in patients suffering from puerperal fever. He recognized that the hands of students working in dissecting rooms carried contagious material to the patients subsequently attended. To check this, he enforced the use of chlorinated lime as a hand wash to remove the cadaveric particles which he believed were conveyed to the pregnant women through the agency of the examining finger.⁸ By thoroughly disinfecting the hands and washing them in chlorine, Semmelweis was able to reduce the mortality due to sepsis from 18% in 1847 to 1.27% of the 3,556 patients delivered during 1848. Later he recognized that putrid discharges from puerpera and infected wounds also conveyed the disease. Semmelweis finally learned, figure 6, that disinfection of the examining hand alone did not prevent puerperal sepsis and recognized that isolation of the lying-in chamber, as advocated by White, terminal disinfection, as demonstrated by Collins, and the avoidance of instrumental trauma to the birth canal were essential to complete control.⁹ Semmelweis' career was unhappy because of the fruitless controversy his writings stimulated and because a reactionary profession did not apply his life-saving principles. His broodings led to his admission to a hospital for the insane in Vienna, where he succumbed in 1865 to spreading infection from a pricked finger.

⁸ HEBRA, F. Höchst wichtige Erfahrungen über die Aetologie der in Gebäranstalten epidemischen Puerperalfieber. *K.K. Gesellschaft der Ärzte zu Wien, Zeit.*, 4:242-244, 1847-1848

⁹ SEMMELWEIS, I. *Die Aetologie, der Begriff und die Prophylaxis des Kindbettfiebers*. Pest, 1861

The appearance of Louis Pasteur's *Mémoire on Alcoholic Fermentation*,¹⁰ figure 7, is significant in the development of aseptic technic because it influenced the thinking of two clinicians Spencer Wells, who enjoyed the reputation of being the "absolutely safe ovariectomist,"¹¹ despite a postoperative mortality of 34%, interpreted Pasteur's work as demonstrating that cleanliness and isolation prevented postoperative infection. On the basis of statistical studies¹² he convinced himself that sepsis was more frequent in large crowded hospitals than in small ones. His thought on hospital construction is responsible for the pavilion type hospital with provisions for the isolation of postoperative and septic patients. By applying his convictions, he was able to reduce his postoperative mortality to 11% in 1882.

The growth of the concept of asepsis resulted from Pasteur's work being read by Joseph Lister, a physiologist and surgeon who had already established himself as a scientist. His work on smooth muscle, the histology of the retina, the clotting of blood, the inflammatory reaction, were notable contributions.¹³ He repeated and confirmed Pasteur's work and applied it to the treatment of compound fractures, figure 8. He demonstrated that they could be converted into simple fractures by proper excision of the devitalized tissue and the application of an antiseptic dressing.¹⁴ As a result, his mortality from compound fractures dropped from 45% to 9%. Lister tried the

¹⁰ PASTEUR, LOUIS. *Mémoire sur la fermentation alcoolique*. Imprimerie de Mollet-Bachelier, Paris, 1860.

¹¹ GARRISON F. H. *An Introduction to the History of Medicine*. Philadelphia: W. B. Saunders Co., 1929. 4th edition, p. 601.

¹² WELLS, SPENCER T. Some Causes of Excessive Mortality after Surgical Operations, *Brit M J.*, 2:1384, 1864.

¹³ *The Collected Papers of Lord Joseph Baron Lister*. Oxford: Clarendon Press, 1909.

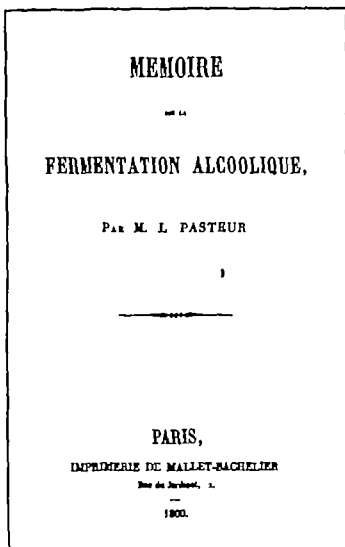


FIGURE 7

Facsimile of the title page of *Mémoire on Alcoholic Fermentation* by Louis Pasteur, Paris, 1860.

same approach to the treatment of tuberculous abscesses, which, earlier had always become secondarily infected following drainage.¹⁵ He showed that with drainage such wounds would heal, provided they were protected from contamination from the air by suitable antiseptic dressings. He next applied his theory of protection against air borne contamination to the

¹⁴ LISTER, JOSEPH. On the New Method of Treating Compound Fracture, Abscess, etc., with Observations on the Conditions of Suppuration. Part I on Compound Fracture, *London Lancet* 1:364-418, 622, 1867.

¹⁵ LISTER, JOSEPH. On the New Method of Treating Compound Fracture, Abscess, etc., *Lancet*, 2:95, 1867.

ON A
NEW METHOD OF TREATING COMPOUND
FRACTURE, ABSCESS, ETC.

WITH OBSERVATIONS ON THE CONDITIONS OF
SUPPURATION.

By JOSEPH LISTER, Esq., F.R.S.,
Professor of Surgery in the University of Glasgow.

PART I
ON COMPOUND FRACTURE.

THE frequency of disastrous consequences in compound fracture, contrasted with the complete immunity from danger to life or limb in simple fracture, is one of the most striking as well as melancholy facts in surgical practice.

FIGURE 8

Facsimile of the title of an article, On a New Method of Treating Compound Fracture, Abscess, etc., by Joseph Lister, *Lancet*, 1:326, 1867

treatment of surgical wounds, figure 9, with the remarkable result that postoperative sepsis disappeared¹⁶

It is interesting that Lister's antiseptic — carbolic acid — was suggested to him by a pharmacist who had seen it used to purify the sewage dumped on the pastures at Carlisle. The pharmacist took the disappearance of the odor and the marked improvement in the health of the cattle pastured on the sewage disposal fields as an indication of the beneficial effect of carbolic acid. Lister's experiments demonstrated the antiseptic action and also the fact that the coagulum formed by blood and tissue when mixed with carbolic acid was slowly organized into a dense, smooth scar.

Pasteur's clear-cut evidence that fermentation was due to air-borne bacteria led Lister to adopt the carbolic acid spray to protect surgical wounds. The same method has been revived by those who use aerosols. Gradually, he extended the use of car-

¹⁶ LISTER, JOSEPH. On the Antiseptic Principle in the Practice of Surgery, *Lancet*, 2:353, 1867

ON THE ANTISEPTIC PRINCIPLE IN THE
PRACTICE OF SURGERY *

By JOSEPH LISTER, Esq., F.R.S.,
PROFESSOR OF SURGERY IN THE UNIVERSITY OF GLASGOW

IN the course of an extended investigation into the nature of inflammation, and the healthy and morbid conditions of the blood in relation to it, I arrived, several years ago, at the conclusion that the essential cause of suppuration in wounds is decomposition, brought about by the influence of the atmosphere upon blood or serum retained within them, and, in the case of contused wounds, upon portions of tissue destroyed by the violence of the injury.

FIGURE 9

Facsimile of the title of an article, On the Antiseptic Principle in the Practice of Surgery, by Joseph Lister, *Lancet*, 2:95, 1867

bolic acid as a lotion for irrigating surgical wounds and the preparation of the materials used at operation but his fundamental contribution still remains the antiseptic dressing which isolates a wound and permits primary wound healing. His technic was so good that blood which pooled in cavities was organized during healing by fibroblasts and firm cicatrization occurred. Although Lister described this repeatedly, he failed to appreciate the significance of the observation and perpetuated the custom of leaving drains in wounds so that blood and serum might leak out. He investigated various antiseptics and, indeed, used dry cotton sterilized by chlorine gas in 1870, but found that discharges from the wound saturated the cotton and that bacteria subsequently caused putrefaction of these discharges. He also contributed the process of chromaturing catgut to delay its absorption. His original idea of tanning the gut with chromic acid is still fundamental.

Lister's concept of preventing postoperative infections met with much resistance and even ridicule but several Continental surgeons adopted the technic immediately and developed it further. A big contributor,

Ernst von Bergmann, abandoned carbolic acid and its spray and substituted asepsis based on the use of bichloride of mercury.¹⁷ Von Bergmann's technic called for pre-operative sterilization of instruments, dry goods, and the hands by soaking them in bichloride of mercury. At the close of an operation, the wound was also irrigated with an aqueous solution of bichloride. Von Bergmann's outstanding contribution was the concept of hemostasis, which he claimed left a dry wound that offered no media to nourish putrefactive organisms. This concept contrasted sharply with Lister's technic of draining the wound and is a significant factor in primary wound healing. In 1889, von Bergmann published a lengthy article,¹⁸ figure 10, on the antiseptic treatment of wounds with bichloride of mercury, which influenced surgeons everywhere and because of confusion in identity with Adolph von Bergmann, led to Ernst's being credited as the father of aseptic surgery.

Many of the developments in aseptic technic were contributed by Gustav Neuber, who recognized that intricately carved, bone handled instruments were difficult to clean and hence dangerous. He introduced plain surfaced instruments which could be taken apart readily for thorough cleansing.¹⁹ He rid the operating room of excess furniture and provided glass shelves and surfaces which could be cleansed readily, until by 1880, his instruments and operating rooms had a modern appearance. In 1882, he introduced the use of the cap and gown as a way of excluding the surgeon's clothing

Die antiseptische Wundbehandlung in der
Kgl. chirurgischen Universitäts-Klinik zu Berlin.

Von
Professor Dr. Ernst von Bergmann,
Chefarzt Medicinisch und Chirurgisch.

FIGURE 10

Facsimile of the title of an article, The Antiseptic Treatment of Wounds in the Royal Surgical Clinic of the University of Berlin by Ernst von Bergmann, *Jahrb. Klin. Chir.* 1:147 1889

from the operating field.²⁰ His technic was so successful that a year later he abandoned the irrigation of wounds with antiseptic solution and substituted sterile 0.6% sodium chloride produced in a water sterilizer which he invented, figure 11. He attached great importance to the complete obliteration of all dead spaces in wounds and advocated the abandonment of drains.²¹ He wrote two small monographs^{22, 23} on his concept of aseptic technic which were influential in spreading the doctrine of safe surgery.

Ernst Kuster's paper on the use of buried sutures perpetuated the fear of leaving pools of blood in dead spaces so much that the treatment of wounds became a mechanical problem involving compression from without, buried sutures, inverting sutures, flap implantations, firm coaptation of the resected

¹⁷ VON BERGMANN, ERNST: Ueber antiseptische Wundbehandlung, *Deutsch. Med. Wochenschr.*, 8:559 1882.

¹⁸ VON BERGMANN, ERNST: Die antiseptische Wundbehandlung in der königlichen Chirurgischen, Universitäts-Klinik zu Berlin, *Jahrb. Klin. Chir.*, 1:147 1889.

¹⁹ NEUBER, GUSTAV: Ueber die Veränderungen decalcierter Knochenrohre in Weichtheilwunden und fernere Mittheilungen über den antiseptischen Dauerverband, *Arch. f. Klin. Chir.*, 23:116, 1880.

²⁰ NEUBER, GUSTAV: *Die aseptische Wundbehandlung in neuen chirurgischen Privat-kospitälern*. Kiel: Lipsius & Tischer 1886.

²¹ NEUBER, GUSTAV: Vorschläge zur Beseitigung der Drainage für alle frischen Wunden, *Mitt. u. d. Chir. Klin. zu Kiel* 1:27-70 1884.

²² NEUBER, GUSTAV: *Kurze Beschreibung der aseptischen Wundbehandlung*. Kiel und Leipzig: Lipsius & Tischer 1892.

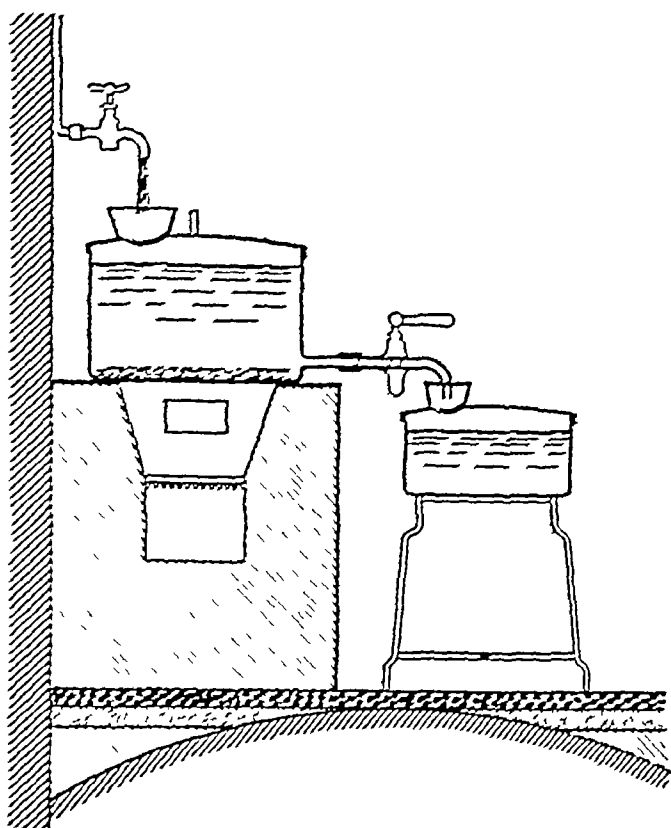


FIGURE 11

Illustration of a water sterilizer devised by Gustav Neuber in 1883, published in his monograph, *The Aseptic Treatment of Wounds in My Private Surgical Hospital*, Kiel, 1886

ends of bones, canalization by loose stitching and secondary closure.²²

The giant in disseminating the knowledge of aseptic technic was Curt Schimmelbusch, one of Ernst von Bergmann's assistants, who spent much time evaluating and elaborating the various details of the aseptic ritual. He first used the steam sterilizer for the sterilization of surgical dressings in 1885, figure 12. In 1891,²⁴ he demonstrated that hand brushes often conveyed sepsis from the careless surgeon who used them to scrub pus from his fingers to another surgeon who used the brushes for the preoperative scrub-

²² KUTTER, E.: Ueber die Anwendung versenkter Nähte insbesondere bei plastischen Operationen. *Arch f. Klin. Chir.*, 31:126-134, 1885.

²⁴ SCHIMMELBUSCH, CURT: Die Durchführung der Asepsie in der Klinik des Herrn Geheimrath von Bergmann, in Berlin, *Arch f. Klin. Chir.*, 42:123, 1891.

bing of his hands. He advocated boiling nail brushes to break this link in the chain of sepsis. He emphasized the fact that the addition of 1% sodium carbonate to boiling water prevented the corrosion of instruments and increased its bactericidal efficiency. His *Aseptic Treatment of Wounds* was the small monograph which spread throughout the world the aseptic ritual he had developed in Von Bergmann's clinic.

The concept of operating in a dry bloodless field was first introduced in 1865²⁵ by Lister, who obtained a bloodless field by elevating the extremity to drain out excess blood and then occluding the vessels by the use of a tourniquet.

Friedrich von Esmarch in 1880²⁶ extended this technic by wrapping the elevated extremity from its distal toward its proximal end with a thin rubber bandage to express the blood before the tourniquet was applied. In 1882, Ernst von Bergmann advocated accurate hemostasis to keep the operative field dry.¹⁷ Dry dressings were introduced by F. von Esmarch and his student, Hans Schlange²⁷ in 1884 for small wounds and their use was gradually extended to larger ones. Albert Sigmund Landerer^{28, 29, 30} and Adolph von Bergmann³¹ in 1889 wrote papers describing a dry technic in which hemostasis, the use of dry sponges, and the abandonment of irrigation of the wound

²⁵ LISTER, J.: Effect of the Position of a Part on the Circulation through It, *Brit M J*, 1:923, 1879.

²⁶ ESMARCH, F.: Ueber ganz blutlose Operationen, *Arch f. Klin. Chir.*, 25:691, 1880.

²⁷ SCHLANGE, H.: Ueber sterile Verbandstoffe, *Verhandl. d. deutsch. Gesellsch. f. Chir.*, 2:141, 1887.

²⁸ LANDERER, A.: Ueber trockene Operationen, *Verhandl. d. deutsch. Gesellsch. f. Chir.*, 2:76, 1889.

²⁹ LANDERER, A.: Trockene Operationen, *Arch f. Klin. Chir.*, 39:216, 1889.

³⁰ LANDERER, A.: Antiseptische und aseptische Wundbehandlung, *Correspondenz der sächs. ärztlich. Vereine und Bezirksvereine*, 1:53, 1892.

³¹ BERGMANN, A.: Ueber die trockene Wundbehandlung, *St. Petersburg Med. Wochenschr.*, 6:455-457, 1889.

were striking features. Thus, Landerer and A. von Bergmann established a technic providing the dry operative field as we know it today.

A significant contribution to aseptic technic came indirectly from William Stewart Halsted, who introduced the use of rubber gloves in 1889 as a means of protecting his scrub nurse's hands from contact with solutions of bichloride of mercury, which had provoked dermatitis.²² The gloves were used for five years for this purpose in Halsted's clinic before Joseph C. Bloodgood recognized their advantage in excluding the operator's hands from the field.²³

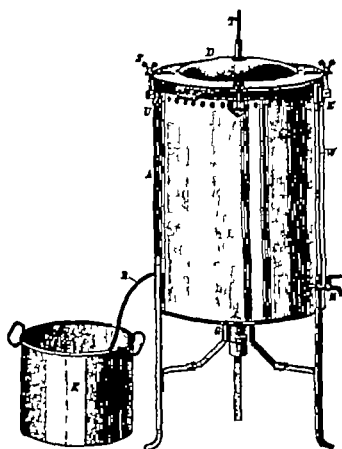
Of greater importance, Halsted correlated the various technics for the treatment of surgical wounds²⁴ and demonstrated that aseptic and surgical technic must be blended to achieve perfect healing of wounds. Schede's article²⁵ on the healing of wounds under a moist blood scab confirmed his own observations and influenced his thought. He emphasized the things a surgeon does to assure wound healing, including (1) hemostasis, preferably by transfixion of large vessels and by the use of hot saline pads to check oozing,²⁶ (2) the use of fine non absorbable suture material, (3) the exclusion of drains,²⁷ (4) the avoidance of

²² HALSTED, W. S. The Employment of Fine Silk in Preference to Catgut and the Advantages of Transfixing Tissues and Vessels in Controlling Haemorrhage, *J. A. M. A.*, 60:1119 1913.

²³ BLOODGOOD, J. C. Operations on 459 Cases of Hernia in the Johns Hopkins Hospital from June, 1889 to January 1899. The special consideration of 268 cases operated on by the Halsted method and the transplantation of the rectus muscle in certain cases of inguinal hernia in which the conjoined tendon is obliterated, *Johns Hopkins Hosp. Rep.*, 7:1223-562, 1898-1899.

²⁴ HALSTED, W. S. The Treatment of Wounds with Special Reference to the Value of Blood Clot in the Management of Dead Spaces, *Johns Hopkins Hosp. Rep.*, 2:255-314 1891.

²⁵ SCHEDE, M. Ueber die Heilung von Wunden unter dem feuchten Blutchoff. *Deutsch. med. Wochenschr.*, 12:389-391 1886.



Apparat zur Dampfsterilisation der Verbandstoffe von Leutnant H. v. Bergmann

FIGURE 12

An illustration of the steam sterilizer used by Curt Schimmelbusch for the sterilization of dressings in 1885 from an article, Aseptic Practice in von Bergmann's Clinic, *Arch. f. Klin. Chir.*, 42:123 1891.

tension that strangulates tissue, (5) the elimination of devitalized nubbins of tissue distal to ligatures, (6) dependence upon tissue fluids to fill dead space in wounds that are permitted to fall together naturally, (7) the use of gutta serena tissue on surface wounds (8) the application of silver foil on wounds to inhibit growth of organisms in the skin. All these points characterized Halsted's work and led to the establishment of a technic that deserves widespread adoption.

²⁶ HALSTED, W. S. Notes on New Books — Anleitung zur aseptischen Wundbehandlung, *Johns Hopkins Hosp. Bull.*, 3:163, 1892.

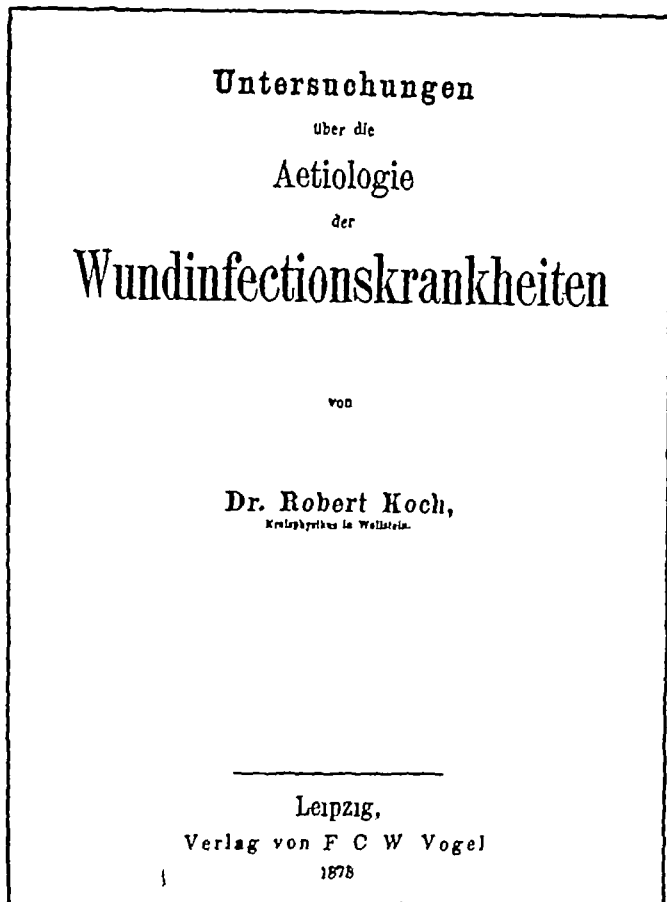


FIGURE 13

Facsimile of the title page of *Traumatic Infectious Diseases*, Robert Koch, Leipzig, 1878

Following the bacteriologic lead blazed by his colleague, Carl Flugge,³⁷ Johann von Mikulicz-Radecki in 1896 first used the mask to control bacteria expired from the nose and mouth³⁸

It must not be surmised that clinicians alone developed aseptic technic because bacteriologists also contributed to progress following the original stimulus by Pasteur¹⁰ In addition to linking bacterial action to fermentation and putrefaction, Pasteur furnished bacteriologic proof that heat destroyed the organisms He described the use of boiling water and dry heat at 120–

³⁷ FLUGGE, C Ueber Luftinfection, *Ztschr f Hyg u Infektionskr*, 25 179, 1897

³⁸ MIKULICZ, J Das Operiren in Sterilisirten Zwirn Handschuhen und mit Mundbinde, *Centralbl f Chir*, 24.713, 1897

130°C as effective Lucas-Championnière designed a steam sterilizer for Pasteur and subsequently used it in his surgical practice in 1876³⁹

In 1878, Robert Koch published a small monograph entitled *Investigations into the Etiology of the Traumatic Infective Diseases*⁴⁰ in which he demonstrated that the organisms described by Pasteur actually could be found in infectious lesions and established criteria whereby the causal organism could be identified In 1881, Koch published a large monograph on antiseptics which influenced surgery greatly in that his description of bichloride of mercury as a germicide led to its widespread popularity.⁴¹

In 1881, Robert Koch and Gustav Wolffhugel⁴² popularized the hot air sterilizer and evaluated the bactericidal power of dry heat Koch, George Gaffky, and Friederich Loeffler⁴³ described the flowing steam sterilizer and established its bactericidal value Hugo Davidsohn, also in Koch's laboratory, justified the use of boiling water in 1888⁴⁴ as being a practical means of minimizing postoperative sepsis instead of waiting for the more ideal steam sterilizers to become available In doing this, he influenced aseptic technic profoundly for instruments are still sanitized by boiling water in most hospitals despite the fact that they are

³⁹ LUCAS-CHAMPIONNIÈRE, J *Chirurgie antiseptique Principes, modes d'application et resultats du pansement de Lister* Paris J B Bailliere et fils, 1876

⁴⁰ KOCH, R Ueber die Aetiologie der Wundinfektionskrankheiten Leipzig Vogel, 1878

⁴¹ KOCH, R Ueber Desinfection, *Mitt a d Kaiserl Gesund*, 1 234, 1881

⁴² KOCH, R and WOLFFHUGEL, G Untersuchungen über die Desinfection mit heisser Luft, *Mitt a d Kaiserl Gesund*, 1 301, 1881

⁴³ KOCH, R., GAFFKY, G, and LOEFFLER, F Versuche über die Verwerthbarkeit heisser Wasserdämpfe zu Desinfectionszwecken, *Mitt. a d Kaiserl Gesund*, 1 322, 1881

⁴⁴ DAVIDSOHN, H Wie soll der Arzt seine Instrumente desinficiren? *Berl Klin. Wchnschr*, 25.697, 1888

frequently contaminated with dangerous organisms which merit a more reliable technic. The original steam sterilizer was shown by Max Globig to be ineffectual against spores⁴⁰ and in 1889, a French orthopedic surgeon, Paul Redard, demonstrated that the temperature of steam in a sterilizer could be raised by increasing its pressure and that this increased temperature was effective in destroying spores.⁴¹

Technical advance was rapid. Most of the contents of Chapters III–XIII were evaluated and applied in various surgical clinics prior to 1900. Surgeons busied themselves in extending the frontiers of surgery in fields made safe by asepsis. Surgical technic was the fascinating pursuit and as subordinates assumed the responsibility for aseptic technic, many of the earlier lessons

were either forgotten or applied in a garbled form. The development of the steam sterilizer is illustrative. The detrimental effect of air in the sterilizer,⁴² the hazard of superheating,⁴³ the protection afforded bacteria by oil and grease,⁴⁴ the advantage of gravity air clearance, the influence of sterilizer design on efficiency, the necessity of measuring the bactericidal power of steam by taking its temperature⁴⁵ were recognized in scattered clinics. Some surgeons boasted ideal equipment but visitors to their amphitheatres came to see operative procedures and returned home to improvise equipment and technic to enable them to do the surgery they had witnessed. The important details of the steam sterilizer were forgotten, to be rediscovered during the past twenty years.

⁴⁰ GLOBIG, M. Ueber einen Kartoffelbacillus mit ungewöhnlich widerstandsfähigen Sporen, *Zucker f. Hyg. u. Infektionskr.*, 3:322, 1888.

⁴¹ REDARD, P. Desinfection des instruments chirurgicaux et des objets de pansement, *Rev. de Chir.* 8:360, 1888.

⁴² RUNKE, M. L. Zur Theorie der Dampfdesinfection, *Hyg. Rund.*, 8:721, 1898.

⁴³ VON EDMARCH, E. Die desinficirende Wirkung des strömenden überhitzten Dampfes, *Zucker f. Hyg. u. Infektionskr.*, 4:197, 1888.

⁴⁴ TEUSCHER, H. Beiträge zur Desinfection mit Wasserdampf, *Zucker f. Hyg. u. Infektionskr.* 9:492–527, 1890.

⁴⁵ FROEHL, P. and CLARENKACH, A. Ueber das Verhalten des Wasserdampfes im Desinfectionsapparate, *Zucker f. Hyg. u. Infektionskr.*, 9:183, 1890.

CHAPTER III

CHEMICAL DESTRUCTION OF BACTERIA

I have divers times put a little vinegar into a little pepper-water and have always seen that as soon as the pepper-water was mixed with the vinegar the animalcules that were in the pepper-water died instantly

— ANTHONY VON LEEUWENHOEK, 1692¹

Chemical disinfection is a highly controversial field because technics for evaluating the efficiency of germicides vary. Much of the literature has little significance due to the failure of investigators to realize that many disinfectants are bacteriostatic in high dilutions and hence inhibit the growth of cultures instead of actually killing them. Many investigations are valueless because the concentration of germicide used is not stated or other extenuating circumstances such as conditions at the germicide-organism interface or the resistance of the cultures used for the test are not recorded. Most laboratory tests are not susceptible of clinical interpretation because the conditions of the experiment are not similar to those found in clinical problems.

Of late, several technics for testing organisms have influenced the thought on germicides because they are performed under the conditions of actual use.^{2 3 4} Another influence which is clarifying thought on germicides is the attitude of the United States Department of Agriculture which insists that the word "sterile" should not be used

as the end result of chemical action. This attitude results from the repeated demonstration that germicides are more often bacteriostatic than germicidal, hence the term "chemical disinfection" is more suitable than the absolute term "sterilization."

Chemical disinfection is resorted to in the operating room only when other methods are destructive and chemicals must be used to preserve the instruments to be sterilized or because there is no expedient way of using more reliable methods of sterilization. When used with the full realization that germicides are highly selective, erratic, and unreliable unless applied carefully, they contribute greatly to aseptic technic. Because germicides are contact medicinals and their activity begins at the medicinal-organism interface, the adsorption of germicides at surfaces is a fundamental property. The adsorption concentration equilibria rather than the concentration of the germicide influence their effectiveness. This concept is important because anyone who uses

¹ DOBELL, CLIFFORD. *Anthony von Leeuwenhoek and His Little Animals*. New York, Harcourt, Brace and Company, 1932, p. 151.

² PRICE, P. B. Ethyl Alcohol as a Germicide, *Arch. Surg.*, 58:528-542, 1939.

³ BREWER, J. H. Antibacterial Effects of Organic Mercurial Compounds, with Special Reference to Their Use as Germicides for Sterilization of Surgical and Dental Instruments, *J. A. M. A.*, 112:2009-2018, May 20, 1939.

⁴ SPAULDING, E. H. Studies on Chemical Sterilization of Surgical Instruments, Bacteriological Evaluation, *Surg., Gyn. & Ob.*, 69:738-744, 1939.

a germicide has direct control of the adsorption concentration because the cleanliness of the surface to be disinfected is of major importance in determining what the effective concentration of the germicide will be. Absolute cleanliness of the surface to be disinfected is essential for reliable germicidal action. Blood, pus, oil, grease, soap, moisture, all decrease or nullify the effect of germicides. It has often been demonstrated that the very germicide which was intended to destroy organisms may protect them so that they survive. The classic demonstration is that by Robert Koch, who showed that bichloride of mercury protected tubercle bacilli in sputum by precipitating an albuminous shell at the surface of the sputum which protected the bacilli in the moist center for months. The effectiveness of germicides is increased by raising the temperature at which they act and by rubbing the surfaces which are to be disinfected. It is evident from recent work that their effectiveness may be increased by changing the adsorption concentration by the addition of detergents and wetting agents. In this discussion of germicides, they are considered from the point of view of general applicability in aseptic technic. Their general advantages and disadvantages are discussed. Their application is discussed in specific sections dealing with technic.

ALCOHOLS

Ethyl Alcohol

Ethyl alcohol is the most popular skin disinfectant. It is relatively inexpensive, is easily applied, and has detergent and wetting properties. When used properly, it is

GERMICIDAL POWER OF ALCOHOL

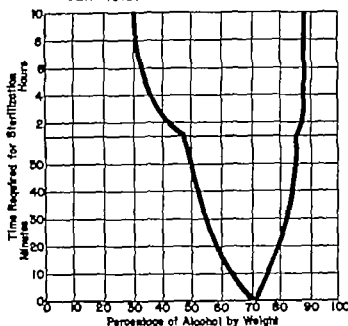


FIGURE 14

Bayer⁷

an effective germicide for vegetative organisms but has little action against spores^{8, 9}. Two factors determine its germicidal power — a lethal concentration of alcohol must be used and sufficient friction to enhance its action must be applied. It has long been recognized that the bactericidal concentration of ethyl alcohol is critical and unless the solution is maintained carefully at the proper level, it is valueless as a germicide. As can be seen in figure 14,⁷ a 70% solution by weight is thirty times as powerful a germicide as 60% and forty times as powerful as an 80% solution. Solutions of less than 50% or more than 80% concentration have no practical value as germicides.

The maintenance of a germicidal concentration of alcohol requires constant supervision because such solutions are unstable and because the definition of 70% alcohol varies greatly. The concentration of alcohol is variously expressed as "volume

⁸ Nye, R. N. and MALLORY, T. B. Fallacy of Using Alcohol for Sterilization of Surgical Instruments, *Bacteriol. Rev.* 8: 561-563 October 18 1923

⁹ KNOKE, M. Ueber den Keimgehalt des Alkohols, *München Med. Wochenschr.*, 79:793 May 13, 1932.

⁷ BAYER, A. In welcher Konzentration tötet wässriger Alkohol allein, oder in Verbindung mit anderen desinfizierenden mitteln Entzündungs- und Eiterungserreger am schnellsten, *Ztschr. f. Hyg. u. Infektionskr.*, 70:225-272, 1911-12.

ALCOHOLOMETER

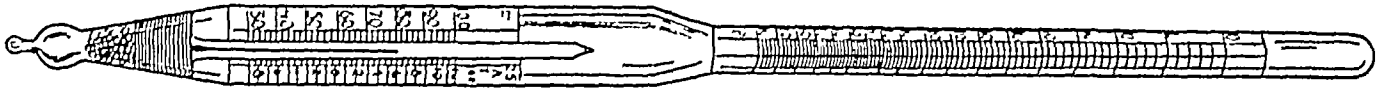


FIGURE 15

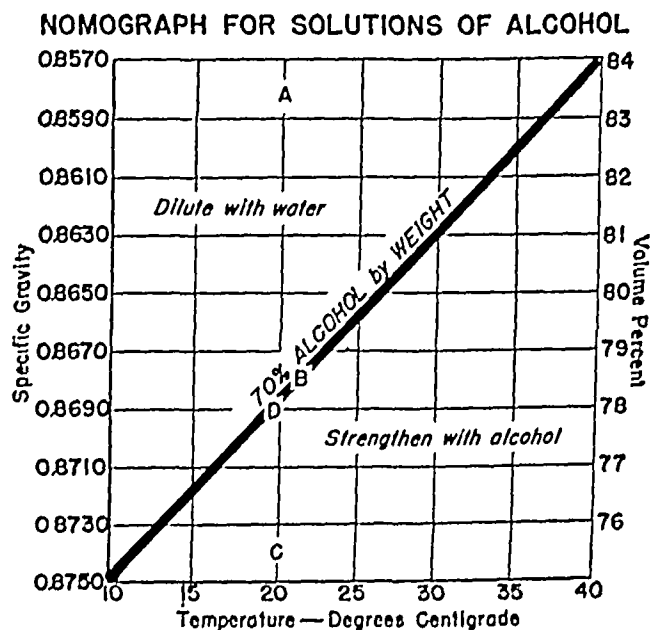
per cent," "weight per cent," or "weight volume per cent," each of which identifies solutions of different concentration, even though the numerical percentage is identical. The specific gravity of alcohol varies greatly with changes in temperature and there is a marked contraction in volume when alcohol and water react together so that the only reliable solutions of alcohol are those made up under a formula which indicates the weight of pure alcohol in the total weight of the solution. This is known as a "weight per cent" solution. Such solutions can be made up initially on a balance without difficulty but since the solutions are so unstable, it is economical to use a technic whereby the concentration can be restored periodically. A formula for the preparation of 70% alcohol by weight is.⁸

Ethyl alcohol (95% at 25°C.)	815 cc
Aqua destillata (cold) q s ad	1000 cc

For ready identification and to make it nonpotable, sufficient cosin to give desired color and 0.1% oil of cajuput may be added. Five per cent acetone serves to denature the germicide. This solution unfortunately is not stable because as evaporation occurs, the loss of water and alcohol is not proportionate. Thus, 70% alcohol evaporated to one-half its weight gradually shifts to 62%. This slight dilution causes a large loss in germicidal efficiency. Similarly, alcohol loses its germicidal efficiency when used repeatedly by careless individuals who

immerse dripping wet arms and thereby dilute the solution.

The solutions of alcohol which have altered their concentration need not be discarded. They can be clarified by filtration through ordinary filter paper and restored to their original strength by the addition of appropriate quantities of commercial alcohol or distilled water. The specific gravity and temperature of a filtered solution of unknown alcoholic content is determined on an alcoholometer, figure 15. This point is found on the nomograph, figure 16, and alcohol or distilled water is added slowly in sufficient quantity to bring the specific gravity of the solution to that indicated on the nomograph for 70% alcohol by weight. For example, if the solution of alcohol in question has a specific gravity of 0.858 and a temperature of 20°C, this point is located



Phillip B. Price

FIGURE 16

⁸ PRICE, P. B. New Studies in Surgical Bacteriology and Surgical Technic with Special Reference to Disinfection of Skin, *JAMA*, 111 1993-96, November 26, 1938

on the nomograph at *A*. Water is then added slowly with stirring until the specific gravity and temperature readings correspond to the line indicated by 70% alcohol by weight. Because heat is liberated as alcohol is diluted the temperature will rise as the specific gravity falls and the point reached will be in the neighborhood of *B*. On the other hand, if the unknown alcohol has a specific gravity of 0.874 and a temperature of 20°C, this point is located at *C* on the nomograph. Alcohol is then added until the specific gravity and temperature readings fall on the 70% by weight line, as is indicated by *D*.

The germicidal efficiency of ethyl alcohol against bacterial flora of the skin is marked. One minute's exposure of the skin to 70% alcohol is equivalent to six and one-half minutes' mechanical scrubbing of the skin. Rubbing the hands and arms with a piece of gauze for three minutes while immersed in alcohol reduces the bacterial flora to about 3% of its original size. Twenty minutes' rubbing will yield skin which is relatively sterile.⁹

Ethyl Propyl Alcohol Solution

A more stable mixture of alcohols with powerful germicidal properties for skin disinfection has the following formula

Ethyl alcohol (95%)	675 cc.
N-propyl alcohol (C.P.)	250 cc.
Aqua destillata	250 cc.

Each minute the skin is immersed in this solution affords disinfection equivalent to approximately eleven minutes of scrubbing.⁹

Isopropyl Alcohol

Isopropyl alcohol can be used for disinfection instead of ethyl alcohol. It is inexpensive, tax-free, nonpotable, and pleasant to use. The dilution for maximum germicidal power is not critical, 30% to 50% solutions

⁹ PRICE, P. B. Ethyl Alcohol as a Germicide, *Arch. Surg.*, 38:528-542, 1939

being adequate. Like the other alcohols, it destroys vegetative organisms but has no effect on spores.¹⁰

CHLORINE COMPOUNDS

Since 1829, when Antoine Labarraque introduced chlorinated lime as a disinfectant in the French catgut industry, chlorine has influenced the course of obstetrics, surgery, and sanitary engineering profoundly. It is the most widely used of all chemical disinfectants and one of the most reliable. Disadvantages which militate against more widespread use are that it has a persistent odor which is objectionable to some, its bleaching action is marked, it corrodes metal instruments and accelerates the deterioration of rubber. The germicidal action of chlorine is due to the formation of hypochlorous acid which acts upon the protein molecule so that the chlorine replaces the hydrogen in amino groups forming a chloramine which is toxic to bacteria. Thus, after bacteria have been exposed to chlorine, any remaining chlorine may be neutralized without influencing the logarithmic rate at which surviving bacteria continue to succumb to the action of the chloramine. Chlorine is most active in approximately neutral solution and its activity is increased markedly by increasing the temperature of the solution.^{11, 12, 13}

The most familiar form in which chlorine is encountered in surgery is as the diluted

¹⁰ COULTHARD, C. E. and SYKES, G. The Germicidal Effect of Alcohol with Special Reference to Its Action on Bacterial Spores, *Pharmaceutical J.*, 137:79-81 July 1936.

¹¹ TORNEY, F. O., GREER, F. E. and DANFORTH, T. F. Minimal "Chlorine Death Points" of Bacteria (Vegetative Forms) *U. S. Nav. M. Bull.*, 27:238-242, January 1929.

¹² TORNEY, F. O., GREER, F. E. and LINDO, G. F. Minimal "Chlorine Death Points" of Bacteria Vegetative Forms; Spore-bearing Organisms, *Am. J. Pub. Health* 40:503-508, May 1930.

¹³ McCULLOCH, E. C. *Disinfection and Sterilization*. Philadelphia. Lea & Febiger 1936, p. 387.

solution of sodium hypochlorite (Dakin's Solution — liquor sodae chlorinatae chirurgalis U.S.P.). This solution is neutral, contains 0.43% to 0.48% sodium hypochlorite, and is tolerated by tissues. It is particularly effective because it dissolves necrotic tissue. Because it macerates and irritates the skin, it can be used continuously only when the skin is adequately protected by vaseline gauze dressings. It is nontoxic when applied topically. It must not be injected into the peritoneal cavity. It should be stored in a cool place in a brown glass bottle because sunlight causes its decomposition.

The U.S.P. XII solution of sodium hypochlorite (liquor sodii hypochloritis) is widely used as a powerful disinfectant for textiles, dishes, dairy equipment, etc. It is available under various trade names, "Clorox" being a well-known example. The active ingredient is sodium hypochlorite; the U.S.P. solution contains between 4% and 6%. For the disinfection of floors, toilets, bedpans, mops, and the like, a solution as dilute as 1:1000 is effective. When diluted to 1:20,000, it is as active as 1% phenol. Sodium hypochlorite can be used with soap and has marked deodorizing power. For the disinfection of drinking water, or for the production of sterile water for operating room use, one-half to one part per million parts of water is reliable. Sodium hypochlorite is also used as an aerosol to disinfect the air of unoccupied premises as discussed in Chapter XX. A convenient form for the disinfection of hands, the skin about compound wounds, and contaminated spots on the floor and furniture is lime paste made according to the following formula:

Chlorinated lime (30% Cl ₂)	200 gm.
Sodium bicarbonate	200 gm.
Sodium carbonate (C.P. Anhyd.) . .	80 gm.

The mixture can be dispensed as a dry

powder. For use, it is mixed in the hands with a sufficient quantity of tap water to make a thin cream. It should be applied immediately and agitated by gentle rubbing. Four minutes of rubbing the skin with this paste is equivalent to twenty minutes of scrubbing the hands with soap and water.⁸

IODINE

Ever since the germicidal action of iodine was first recognized by Casimir Davaine in 1873, it has been applied to skin disinfection. It was one of the first germicides to be used by those who disregarded atmospheric contamination and realized that purification of skin and instruments was more important. One of the most striking characteristics of iodine as a germicide is its uniformity of action on different species of micro-organisms. Tincture of iodine is most popular among surgeons despite the fact that it is an irritant and causes vesiculation. Aqueous solutions are more effective germicides, do not irritate the tissues, and are painless.¹⁴ If applied frequently, solutions of iodine may cause dermatitis in some individuals. Two preparations are readily available. The U.S.P. strong solution of iodine (liquor iodi fortis, Lugol's Solution) can be diluted for the ready preparation of a germicide:¹⁵

Irrigation of tissue	0.1% aqueous solution of iodine (1:50 dilution)
Glove basins . . .	0.5% aqueous solution of iodine (1:10 dilution)
Skin	1.0% aqueous solution of iodine (1:5 dilution)

The U.S.P. XII solution of iodine (liquor iodi) consists of:

¹⁴ JOHNSON, F. F. Surgical Solution of Iodine, *Report to U.S.P. Committee on Revision*, Letter 33.
¹⁵ NYE, R. N. Relative in Vitro Activity of Certain Antiseptics in Aqueous Solutions, *J.A.M.A.*, 108:280-287, January, 23, 1937.

Iodine	20 gm.
Sodium iodide	24 gm.
Distilled water, a sufficient quantity to make	1000 cc.

The secret of success in the use of iodine is the realization that dry iodine has no bactericidal action. The aqueous solution should be applied and rubbed into the skin for approximately one minute and then allowed to dry by evaporation. The dry iodine can be removed with alcohol or sodium hyposulfite. If the skin is greasy, it should be scrubbed with soap and water and the iodine can be applied directly to the lathered area, where it will spread evenly.

Care must be taken not to store iodine solutions near instruments, because sublimated, gaseous iodine is highly corrosive.

FORMALDEHYDE

Formaldehyde gas was heralded as an efficient disinfectant and deodorizer almost as soon as it was commercially available in 1820. Unfortunately, it is used widely as a fumigant even though it is well known that in practice it has little effect other than the psychologic one produced by its odor. In surgery, it finds application as a gas for the disinfection of instruments which are destroyed by heat and which are not conveniently immersed in solutions. Dry formaldehyde gas has no germicidal properties, penetrates poorly, and requires prolonged exposure.^{16, 17} Special equipment permits its use for the disinfection of instruments, figure 19.

Formaldehyde gas has marked deodorizing power and the addition of a paraform tablet to the steam sterilizer in which a foul mattress is to be sterilized is an easy way of

deodorizing it. Care must be taken to vent the steam directly to atmosphere before opening the sterilizer.

Solutions of formaldehyde find wide use in surgery for the disinfection of metal instruments because under proper conditions, formaldehyde kills spores without corroding the instruments. It has several disadvantages. It desiccates and irritates the skin and causes contact dermatitis in susceptible individuals. Residual solutions on instruments irritate the eyes, mucous membranes, and tissues, so that instruments which have been disinfected by submerging them in formaldehyde solutions must be rinsed with sterile water or the solution must be allowed to evaporate completely before using them. Hollow needles should not be sterilized with formaldehyde solutions because it is too difficult to get the irritating germicide out of the cannula. Formaldehyde has one of the greatest temperature coefficients of any disinfectant and it should be used at room temperature or warmer whenever possible. Organic material inhibits its germicidal action somewhat but not as markedly as with other germicides.

For the disinfection of surgical instruments, the following solutions may be used

A. Sodium tetraborate	50 gm.
Solution of Formaldehyde U.S.P.	100 cc.
Distilled water q.s. ad	1000 cc.
B. Solution of Formaldehyde U.S.P.	130 gm.
Potassium nitrite	0.15 gm.
Sodium hydroxide	0.012 gm.
Ethyl alcohol (C.P.) (95%) q.s. ad.	1000 cc.

The minimum routine exposure for the destruction of spores on instruments is eighteen hours. Thirty minutes are required to destroy vegetative forms.¹⁸ For sterilization of the occasional instrument, which can be dependably cleansed before immersion, one

¹⁶ LAURELL, A. Disinfection of Surgical Instruments with Formaldehyde and Formalin, *Internat. Abstr. Surg.*, 63:175 August, 1936

¹⁷ WALTON, L. E. Sterilization of Surgical Instruments, *Hosp. Tid.*, 76:57 January 1933

¹⁸ SPAULDING, E. H. Personal communication, 1937

hour is safe.¹⁹ Erythrosine Certified Color F.D.C No. 3 can be added to formulas in quantity sufficient to give a characteristic color.²⁰ The addition of 0.5% G-11 (dihydroxy-hexachloro-diphenyl methane) to either solution will enhance its action so that disinfection of spores occurs in three hours.

Solutions of formaldehyde are commercially available for the disinfection of instruments, typified by Bard-Parker Improved Formaldehyde Germicide, which destroys spores in three hours,²¹ vegetative organisms in twenty minutes.

The inner surfaces of "sterilizers" for chemical disinfection are disinfected by the vapors given off from the three types of formaldehyde solutions mentioned above. It should be noted that this disinfection, however, is limited strictly to the areas in contact with the formaldehyde atmosphere because cultures taken from the rim of a container where the lid prevented free contact with the formaldehyde showed the presence of viable spores even after twenty-four hours' exposure.¹³

For proper disinfection, rubber goods, Kelly pads, rubber sheets, etc., are given a two-hour exposure to a solution made with the following formula:²²

Solution of Formaldehyde U.S.P.	135 cc
Sodium hydroxide	10 gm
Aqua destillata q s ad	1000 cc

QUATERNARY AMMONIUM SALTS

A new group of germicidal compounds, the quaternary ammonium salts, have properties which make them of interest in sur-

gery. These salts are cationic detergents with marked germicidal power and low toxicity, both systemically and for tissues locally. They are kind to the skin and are pleasant to use. Their action is due to the inactivation of the respiratory enzymes concerned with bacterial metabolism.²³ Several disadvantages are outweighed by their unique properties. Soap robs the compounds of a portion of their germicidal activity and, what is more serious, combines with them to form an irritating substance which causes dermatitis in some individuals. "Sterone" (cetyl-trimethyl ammonium bromide) is a noteworthy exception in that it is compatible with soapy solutions. Their germicidal power decreases with the presence of organic material.

Various brands of quaternary ammonium salts are commercially available. Applied to skin, they form a tough invisible film which retains bacteria under it. Water, saline, soap, or alcohol destroy the film and release bacteria.²⁴ "Zephiran" (N N R) and "Roccal" are brand names for preparations of benzyl-trialkyl ammonium chloride. The former is a purified form which is suitable for topical application. The latter is an industrial brand used for the disinfection of furniture, tableware, or instruments. Both are available in the form of 12.8% concentrates or more dilute aqueous solutions and tinctures. "Phemerol" is the brand name for para-tertiary-octyl-phenoxy-ethoxy-

¹⁹ SPAULDING, E. H. Report of Investigation of Germicidal Properties of Bard-Parker Formaldehyde Germicide, 1937.

²⁰ PAPPEP, M. Personal communication, May, 1943.

²¹ SPAULDING, E. H. Personal communication, May, 1946.

²² LICKER, E. E. and SMITH, R. Sterilizing Surgical Instruments and Utensils, *Mod Hosp*, 48:92, 1937.

²³ SPVAG, M. G. and ROSS, O. A. Studies on the Mechanism of the Inhibitory Action of Zephiran on Yeast Cells, *J Bact*, 48:677-682, 1944.

²⁴ MILLER, B. F., ABRAMS, R., HUBER, D. A. and KLEIN, M. Formation of Invisible Nonperceptible Films on Hands by Cationic Soaps (especially Zephiran and Phemerol, quaternary ammonium compounds), *Proc. Soc. Exper. Biol. & Med.*, 54:174-176, November, 1943.

²⁵ BROWN, W. E., GUNDERSON, M. F., SCHWARTZ, P. and WILDER, V. M. Clinical and Bacteriological Study of Phemerol (quaternary ammonium compound) as Skin Antiseptic, *Surg, Gynec, & Obst*, 78:173-180, 1944.

ethyl-dimethyl-benzyl ammonium chloride monohydrate,²¹ "Ceepryn," that for cetyl pyridinium chloride. Zephuran will be discussed as typical of the group because it has been in use longer. The others can be applied in similar concentrations. The dilutions listed below are effective for clinical use.

*Disinfection of the skin*²²

Zephuran 12.8% concentrate	8 cc.
Aqua destillata q.s. ad.	1000 cc.

*Glove bathes*²³

Zephuran 12.8% concentrate	8 cc.
Aqua destillata q.s. ad.	5000 cc.

Sensitization of tableware, furniture, etc.

Roccal 12.8% or Zephuran 12.8%	8 cc.
Aqua destillata q.s. ad.	2500 cc.

Disinfection of instruments — exposure, 30 minutes for vegetative bacteria, 18 hours for spores

Zephuran 12.8%	8 cc.
Sodium nitrite	10 gm.
Aqua destillata q.s. ad.	1000 cc.

Solutions of Zephuran can be colored by adding sufficient Orange No. 1 and Amaranth No. 107 to yield a solution of desired

shade. Kits of dye are commercially available for the purpose.

A large group of popular germicides may be included under the title, "Germicides Unsuitable for Surgery Where Spores Should Be Killed."²⁴ Bichloride of mercury is highly bacteriostatic but has little bactericidal power.²⁵ It corrodes metal instruments badly and loses much of its power in the presence of organic matter.

Unless used carefully, none of the following group of germicides can be depended upon to disinfect instruments, none kill vegetative bacteria, certainly, in less than thirty minutes' exposure.²⁶ merthiolate, metaphen, merphenyl nitrate, mercarbolid, mercresin, mertoxol, mercurochrome, mercoxyl, mercury oxycyanide, mercuric cyanide, potassium mercuric iodide, mercury chloride, cystane (merphenyl borate).

The time honored phenol group of germicides is also unreliable in that it does not destroy spores even after prolonged exposure. Those containing cresol are more active germicides than phenol.

²¹ WALTER, C. W. Use of Mixture of Coconut Oil Derivatives as a Bactericide in the Operating Room, *Surg., Gynec., & Obst.*, 67:683-688 1938.

²² POPPE, J. K. Wash Basin Contamination in Operating Rooms, *Arch. Surg.* 44:103-107 1942.

²³ PRICE, P. B. Mercurials as Skin Disinfectants, *Bull. Am. Coll. Surg.* In press, 1947.

CHAPTER IV

CHEMICAL DISINFECTION OF INSTRUMENTS

Some preparations clinically ranking as antiseptics owe their reputation to other powers than that of destroying septic material.

—ARTHUR TRACY CABOT, 1879¹

Chemical disinfection of instruments should be limited to those which can be prepared in no other way, because it is time-consuming and unreliable unless carefully supervised and conscientiously performed. The magnitude of the problems encountered is indicated by the fact that a scalpel blade which has been contaminated with pus or exudate carries on it an average of 100,000 bacteria and 2 spores. An occasional knife blade will be found with as many as 15,000,000 bacteria and 15 spores.² Ten per cent of the knife blades which are used during routine operations become contaminated with sporeforming bacteria.³ Instruments used inside the "clean" peritoneal cavity are likely to be contaminated; 80% of cultures taken from the peritoneal cavity as it was first opened showed growth, 14% grew anaerobic organisms.⁴ *Clostridium*

welchii can be demonstrated in 6% of cultures taken from high in the vagina.⁵

To assure prompt germicidal action, instruments must be mechanically clean before immersion in germicide to permit it to contact all bacteria immediately. Because careful cleansing in itself is an effective way of sterilizing instruments, the careless techniques of chemical disinfection in vogue are apparently successful.^{6,7} Even new instruments must be cleansed because they may be covered with a film of grease or oil to protect them against atmospheric corrosion and this film prevents bactericidal action. To avoid diluting the germicide in which instruments are immersed, they must be carefully dried prior to immersion; otherwise, the germicide loses its lethal power and the excess water may cause rusting.

The material of which an instrument is made, as well as the character of the instrument itself, determines the type of germicide to be used. The instrument as a whole

¹ CABOT, A. T.: Experiments upon the Strength of Antiseptics, *Boston M. & S. J.*, 101:755, 1879.

² STAUDING, E. H.: Studies on Chemical Sterilization of Surgical Instruments: Bacteriological Evaluation, *Surg., Gynec. & Obst.*, 69:738, 1939.

³ BRUNER, J. H.: Antibacterial Effects of Organic Mercurial Compounds, with Special Reference to Their Use as Germicides for Sterilization of Surgical and Dental Instruments, *J.A.M.A.*, 112:2004-2018, May 20, 1939.

⁴ ROBERTS, K., JOHNSON, W. W. and BRUCKNER, H. S.: Aseptic Peritoneal Cavity — A Misnomer, *Surg., Gynec. & Obst.*, 57:752, 1933.

⁵ SALK, R.: The Occurrence and Significance of the *Clostridium Welchii* in the Female Genital Tract, *J. Obst. & Gynec. Brit. Emp.*, 51:121, 1944.

⁶ SCHIMMELBUSCH, C.: *The Aseptic Treatment of Wounds* London: H. K. Lewis, 1894, p. 64.

⁷ GILCREAS, F. W. and O'BRIEN, J. E.: Laboratory Studies of Methods for Cleansing of Eating Utensils and Evaluating Detergents, *Am. J. Pub. Health*, 31:143-150, February, 1941.

must resist attack by the germicide. Instruments made of several types of metal may be ruined because the germicide corrodes but one small portion of it, or the working edge may be dulled because the corrosive action of the germicide has not been sufficiently inhibited.

The chief difficulty with chemical disinfection is that it is time-consuming. The strongest applicable germicides require three hours' exposure to reliably destroy spores and at least twenty minutes' exposure to kill vegetative bacteria on instruments that have not been thoroughly cleansed.^{8, 9} Hence, expediency often militates against adequate chemical disinfection.

The various instruments which are usually prepared by chemical disinfection are considered in groups. Certain germicides are recommended for each class along with the technique for their use. With all, it must be realized that successful disinfection frequently entails the use of special equipment, either to provide ideal conditions for germicidal action or to protect the instrument against damage during disinfection. An excellent example of specifically designed equipment fortifying chemical disinfection is that of the transfer forceps.

TRANSFER FORCEPS

Transfer forceps, or sponge sticks, have long been recognized as presenting a particular problem in sterilization and there are many instances^{8, 10} where they have been demonstrated as the source of contamination in an otherwise safe technique. Various modifications have been devised to prevent evaporation of the germicide or to provide

a sterile lip for the jar but none has found wide acceptance and most hospitals continue to use clumsy, makeshift instruments.

A transfer forceps of new design has found wide favor, figure 17. These forceps are unique because the jaws are irregularly serrated transversely and have a crescentic cross section to afford every opportunity for them to grip cylindrical or irregularly shaped objects. They pick up and grasp firmly any instrument from a milliner's needle to a heavy retractor, or a sizable package of dry goods, figure 17, 3 to 7.

The forceps are forged from stainless steel. A pistol-grip handle, substituted for the finger rings of the conventional sponge stick, provides a stronger, more natural grip and is also advantageous because it projects the jaws of the forceps in the axis of the forearm — a position in which the load can be handled most easily with little chance of contamination due to misdirection of the forceps. A bump near the angle of each handle gives additional purchase for the thumb and forefinger and prevents the handle from slipping back into the palm of a large hand.

The legs of the forceps distal to the lock protrude through a hole in a molded disc-shaped piece of rubber which is snapped over projections of the pivot to position it permanently. The rubber forms a barrier, figure 17, 5, between the handle and the sterile legs and jaws distal to it and serves as a cover for the germicide jar, figure 17, 7, effectively preventing evaporation of the germicide.

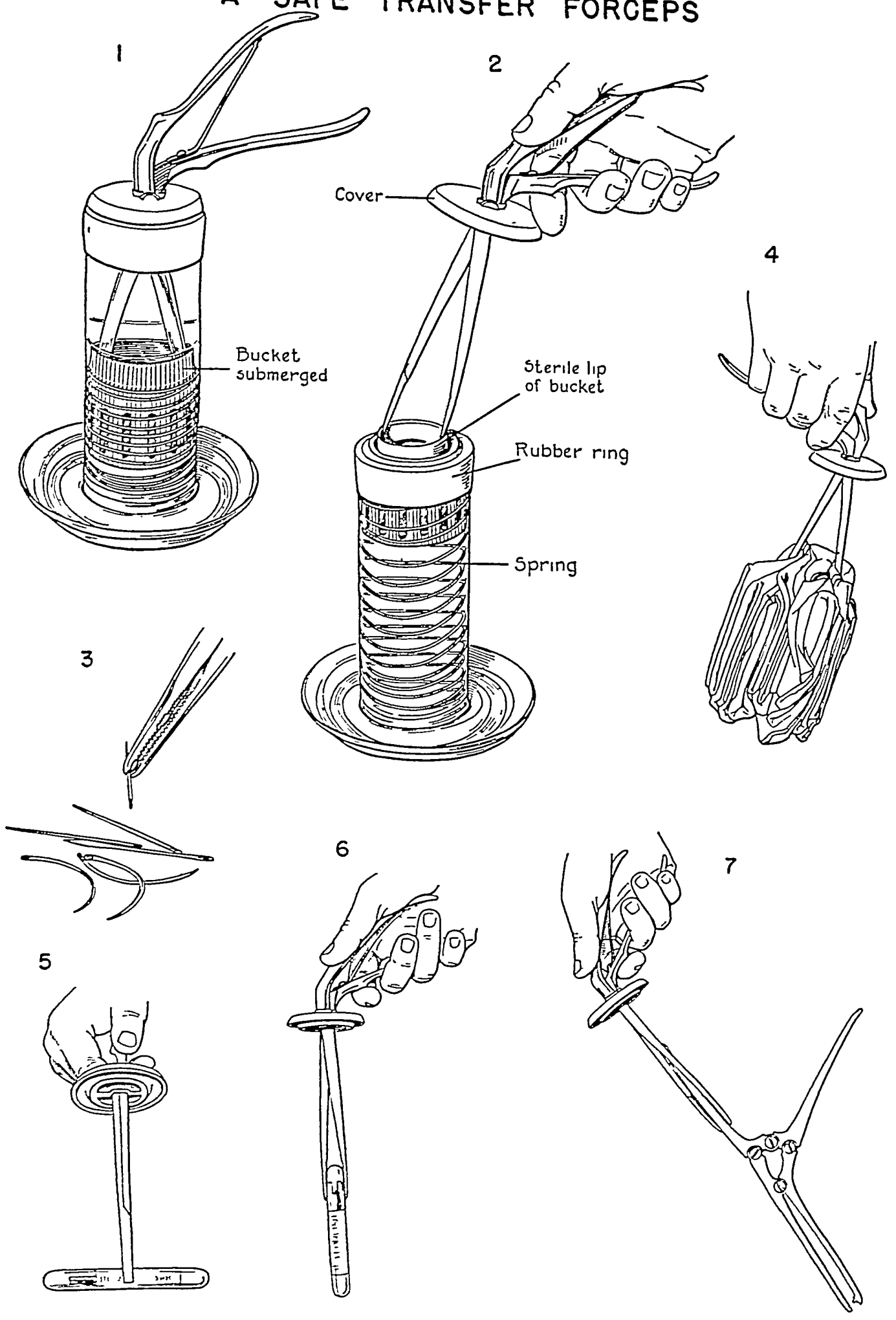
The germicide jar is molded of glass with a saucerlike base to lend stability as well as to catch spilled germicide. The jar is graduated so that the germicide can readily be maintained at the proper level. The upper rim of the glass jar is encased in a molded rubber ring, the upper surface of which bears a beveled lip over which the

⁸ SPAULDING E. H. Personal communication, May 1946.

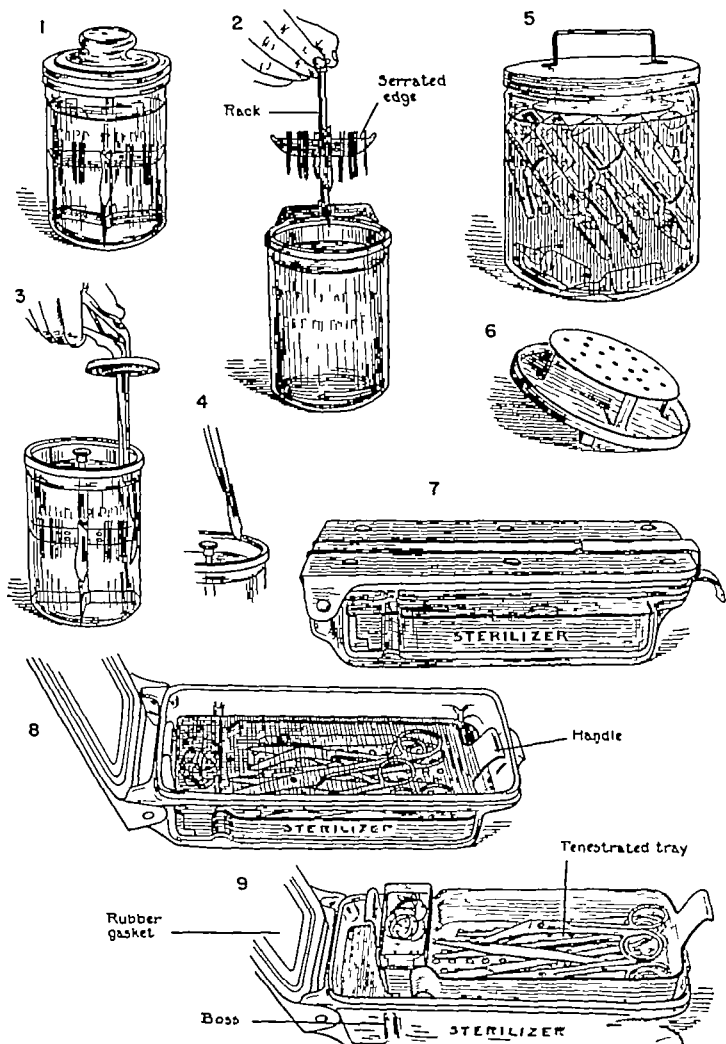
⁹ ECKER, E. E. and SMITH, R. Sterilizing Surgical Instruments and Utensils, *Med. Hosp.*, 48:92, March, 1937.

¹⁰ JANEWAY C. A. Personal communication, August, 1942.

A SAFE TRANSFER FORCEPS



AIDS TO CHEMICAL DISINFECTION



rubber cover attached to the forceps fits snugly, sealing the jar.

The jar is fitted with a fenestrated, piston-like stainless steel bucket which is held against the rubber encasing the upper edge of the jar by a stainless steel coil spring. The rim of the bucket protrudes one centimeter above the rubber, figure 17, 2. When the forceps are put into the jar, their jaws are automatically inserted into the bucket. The weight of the forceps is sufficient to compress the spring and submerge the bucket in the germicide, figure 17, 1. The germicide is displaced by the bucket as it sinks and flows through the fenestrations. When the forceps are lifted, the sterile bucket guards the sterile jaws against contamination by escorting them beyond the unsterile rim of the jar, figure 17, 2.¹¹

CUTTING EDGE INSTRUMENTS

Cutting edge instruments and those so delicate that heat destroys them are commonly disinfected by chemical germicides. Often protection against mechanical injury, for example, dulling of an edge by contact with another instrument, is as important as the selection of a suitable germicide. Special containers are available that provide for safe immersion in germicide. A popular one for the disinfection and storage of scalpel blades, figure 18, 1 to 4, has a rack with serrated arms to space the blades for easy removal as well as to protect them against damage while in the sterilizer.

Instruments can be stored conveniently while immersed in a germicide in a container, figure 18, 7 and 8, which is fitted with a rubber-gasketed lid so that evaporation is reduced to a minimum. The fenestrated tray can be lifted by the handle and positioned on bosses cast in the container to

permit the germicide to drain off, figure 18, 9.

The most reliable germicides to be used for the disinfection of metal instruments depend upon formaldehyde as the active ingredient. Bard-Parker Formaldehyde Germicide typifies a commercially available product which pioneered in the field of corrosion inhibited germicides. The improved solution disinfects in three hours. Sodium tetraborate and formalin mixtures or 5% alcoholic solutions of formaldehyde made up as indicated in the formulas in Chapter III can be used satisfactorily. The period of exposure is thirty minutes for the destruction of vegetative forms, eighteen hours for the destruction of spores.² Germicides containing formaldehyde are irritating to tissue and must be used with care.¹²

RUBBER GOODS

Most rubber articles available at present are disinfected either by exposure to moist heat or by chemical disinfection. Those which are not heat resistant — Kelly pads, sheeting, and the like are soaked in alkaline formalin solution for two hours. As synthetic rubbers appear, care must be taken to select suitable methods for disinfection because "rubber goods" will undoubtedly include articles actually made from many substances with kindred properties, figure 122.

Gutta percha, a substance resembling rubber, softens when heated and must be disinfected in aqueous solutions of germicides.

Shellac, an example of a natural resin, is the resinous incrustation secreted by the scale insect *Laccifer lacca* Kerr of British India. Shellac is destroyed by heat and is attacked by many organic solvents. "Gum elastic," "web," or "shellac" catheters can-

¹¹ WAITER, C. W. Sterile Transfer Forceps, *Am J Surg*, 53:184-186, 1941.

¹² MURPHY, J. L. Infection in Clean Operative Wounds, *Gynec. & Obst.*, 60:264-276, 1935.

not be sterilized by heat without destroying their rigidity. If shellac articles are soaked in tinctures, the gum dissolves so that disinfection must be accomplished either by the use of aqueous germicides or formaldehyde gas.

PLASTICS

Many plastics must be disinfected by chemicals because they are not heat resistant, figure 122

DISINFECTION OF TELESCOPIC INSTRUMENTS

Cystoscopes, thorascopes, and peritoneoscopes present problems in disinfection because they are injured by solvents which attack the cement in which the lenses are set. Alkali attacks the lens glass and makes it opaque and heat loosens and destroys the lens system. This group of instruments is most advantageously disinfected in the formaldehyde gas disinfector or by immersion in an aqueous germicide. War time advance in plastics has produced a heat resistant, transparent substitute for Canada Balsam in which lens systems can be set. Endoscopes incorporating this new cement can be sterilized by exposure to saturated steam at 121°C.¹² The new Kirwin Cystoscope¹⁴ points the way to easier instrument care and safer endoscopic examination because it has been designed to be sterilized by moist heat.

DISINFECTION BY FORMALDEHYDE GAS

Equipment for the proper use of formaldehyde gas is not commercially available. A pressure cooker can be modified to serve as an ideal disinfector.¹⁵ A 300-watt ring heater and a thermostat set at 26°C are fastened against the bottom, figure 19, to

FORMALDEHYDE DISINFECTOR

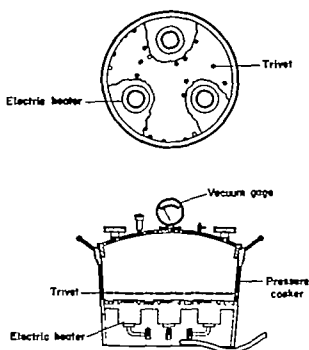


FIGURE 19 Ecker & Pillemer¹⁵

maintain minimum germicidal temperature. The lid is fitted with a stop-cock and nipple so that a 100-mm. vacuum can be drawn. A reservoir for formalin, a metering valve, and an evaporator permit the ready introduction of 12 cc. of formalin. The evaporation of the formalin provides simultaneously the humidity (80% minimum essential) and formaldehyde (0.05 mgm. per cent lethal concentration). The formation of these gases relieves the vacuum and insures penetration of the germicidal gas to all parts of the instruments. Thirty minutes' exposure suffices to disinfect thoroughly clean instruments after all the conditions enumerated above have been attained.

OPHTHALMOLOGICAL INSTRUMENTS

Ophthalmological instruments, particularly the delicate ones, are best disinfected

¹² WALLACE, F. J. Personal communication, July 1946.

¹⁴ KIRWIN, T. J. A New Cystoscope, *J. Urology* 55: 208, 1946.

¹⁵ ECKER, E. E. and PILLEMER, L. Pressure Cooker Sterilizer for Urologic Instruments, *Mod. Hosp.*, 50 86, May 1938. By permission of Modern Hospital Publishing Company Inc.

by immersion in corrosion inhibited 1:1000 aqueous Zephiran because it protects their cutting edges and also is noninjurious to the eyes, whereas formaldehyde residues on such instruments are irritating and must be removed completely by rinsing the instrument in sterile water before it is used. Dry heat is also practicable (Chapter IX). Double-bladed cataract knives and corneal trephines are best sterilized at 121°C for four hours.

UTENSILS, OPERATING ROOM TABLES, FLOORS, PAINT

The most effective method of disinfecting contaminated surfaces in the operating room is to rub them with a solution of 1:1000 sodium hypochlorite. This solution can be used with soap and is an effective means of terminal disinfection. Another effective method is to scrub the contaminated surfaces with a solution of 1:2500 Roccal, allowing the solution to dry on. The use of soap must be avoided because it inhibits the action of this germicide. If the problem is limited to the disinfection of spots of blood or pus, the most suitable germicide is a thin paste of chlorinated lime applied to the contaminated areas for several minutes; it should be agitated occasionally for maximum effect. Where disinfection of a whole room is essential, aerosols (Chapter XIII) are effective and easy to use.

BRUSHES

Chungking bristle brushes (hog bristle) are disinfected by immersion in germicide because even moderate heat causes the bristles to crack and curl. Such bristles cause pain when the brushes are used to scrub the skin and accordingly adequate skin disinfection is too uncomfortable and is not carried out. Brushes must be rinsed free of soap and can be disinfected and

stored in 1:1000 aqueous Zephiran, a 0.5% aqueous solution of iodine or a solution of 1:1000 sodium hypochlorite. Vegetable bristle and synthetic bristle brushes are best sterilized by saturated steam.

SURGICAL GUT

Tubes containing nonboilable gut must be disinfected by chemicals. The germicidal solution must have a low specific gravity so that the tubes will sink and remain submerged. The solution must also be a fat solvent to remove the finger prints which may protect bacteria on the outside of the glass tube. Ordinary candy jars* make ideal disinfecting containers for surgical gut when fitted with a glass partition to separate two sizes of surgical gut. Tubes of gut are packed in the jar and then it is filled with an alcoholic solution of formaldehyde. The jar need not be sterilized previously nor need the surgical gut tubes be washed. The unsterile cover is put in place and the jar is quarantined for eighteen hours. At the end of that period, its contents, including the inner side of the cover, will be found sterile and will remain so until the last tube of surgical gut is used. Jars full of disinfected surgical gut tubes need not be cleansed and re-disinfected just because it is Sunday.

AMPOULES

Ampoules of drugs must occasionally be disinfected for use at the operative field. Ampoules should be selected which have the label imprinted on the glass itself; otherwise, the labels become detached and the identity of the drug is lost. Because many of the drugs are crystalline, they are put up in large ampoules so that there is room for a solute. A germicide with a specific gravity low enough to cause them to sink is not available and a container with a special

* Vita 4250, Glasco Products Company, Catalogue, 1942

cover to keep the ampoules submerged must be provided, figure 18, 5 and 6. Because cracked ampoules are likely to leak, it is desirable to color the germicide so that leaky ampoules can be detected readily before the irritating chemical is injected into the tissues. Dyes should not be added to germicides indiscriminately because many are incompatible and decrease bactericidal

action. Formulas for colored solutions of either formaldehyde or Zephuran suitable for this purpose are listed in Chapter III. The ideal solution is one with vapors that destroy bacteria so that the protruding portion of ampoules and the inside of the cover are disinfected. Alcoholic solution of formaldehyde has these properties.

CHAPTER V

PHYSICAL DESTRUCTION OF BACTERIA

Now the animalcules that are in the white matter on the front teeth, and on the foremost of the back teeth, being unable to bear the hotness of the coffee, are thereby killed: like I've often shown that animalcules which are in water are made to die by a slight heating.

—ANTHONY VON LEEUWENHOEK, 1692¹

Many physical agents destroy or remove bacteria. Mechanical cleansing is the most applicable means for getting rid of gross contamination. The burial of the dead, the central deposition of feces, the scrubbing of hands and the debridement or excision of contaminated wounds are examples of mechanical cleansing which for many years have been relied upon to control disease. Burning has been considered "The Great Purifier" but many forget that it has but a surface effect; that everything must be consumed to be certain of sterilization. Septic dressings or sputum are customarily disposed of by burning. Desiccation is often relied upon for disinfection. Pathogenic, nonsporeforming organisms can readily be controlled by a few hours of desiccation but carefully dried sporeformers have been demonstrated to survive forty years in the anhydrous state.² If nonsporeforming pathogens are desiccated completely in a high

vacuum, it has been shown that they survive indefinitely.³ Sunlight is often relied upon for disinfection.⁴ The action is due partly to the dehydrating and calorific rays but chiefly to the ultraviolet component of sunlight.⁵ The germicidal action of sunlight is poor in cities because the dust in the air reflects or absorbs so much of the ultraviolet radiation that little is left for germicidal action. To be effective, sunlight must strike the object to be sterilized almost perpendicularly, otherwise much of the ultraviolet is reflected.⁶ For this reason, the germicidal action of sunlight is less at the poles than at the equator. At best, it is superficial and, even then, uncertain

Other physical agents can be used for their germicidal action but their use is uncommon or depends upon accessibility to cumbersome equipment. They are of interest chiefly because they are occasionally used in medicine. Electricity alone has no

¹ DOBELL, CLIFFORD. *Anthony von Leeuwenhoek and His Little Animals*. New York: Harcourt, Brace and Company, Inc., 1932, p. 248.

² McCULLOCH, E. C.: *Disinfection and Sterilization*. Philadelphia. Lea and Febiger, 1936, p. 171.

³ FLOSDORF, E. W. and MUDD, S.: Procedure and Apparatus for Preservation of "Lyophilic" Form of Serum and Other Biological Substances, *J. Immunol.*, 29:389-425, 1935

⁴ DOWNES, A.: Researches on the Effect of Light on Bacteria and Other Organisms. *Proc Roy Soc*, 26:488, 1877.

⁵ MARSHALL, H. W. Experiments on the Action of Light on Bacillus Anthracis, *Proc Roy Soc*, 52:393, December, 1892.

⁶ MEADER, F. M.: Sunlight as Disinfectant, *J. Michigan M Soc.*, 25:636-645, December, 1926

germicidal action except that high frequency electricity generates heat in tissue and hence, indirectly, is a germicide. The endothermy knife is a good example.⁷ Hard Roentgen rays (wave length 0.0-1.5 Å) are highly bactericidal but are seldom used because the hard x ray has a deleterious action on the skin.⁸ Alpha or beta rays emitted from radium also have germicidal action. Sonic waves in the neighborhood of 800,000 cycles per second have been used to pasteurize milk,⁹ and supersonic waves up to 1,500,000 cycles per second have been shown to destroy both bacteria and viruses.¹⁰ Many believe that pressure alone is germicidal and feel that the pressure sterilizer owes its efficiency to the fact that pressure destroys organisms. It has been shown that 7030 Kgm. per sq. cm. exerted for fourteen hours is necessary to destroy vegetative bacteria.¹¹ Most dry spores resist even higher pressures.

The most universally applicable physical agent is heat. It is an age-old observation that temperature affects bacterial life. The preservation of food by chilling is the most useful application of the fact that cold inhibits bacterial growth. The dormant storage of bacterial cultures at -28°C is the modern technic for prolonging the life of cultures in bacteriologic laboratories.¹²

Cold has recently been found effective for controlling infection in arms or legs with poor blood supply.¹³ The refrigerated extremity can be amputated safely without additional anesthesia when the patient's condition warrants operation.

Since the days of Louis Pasteur and Robert Koch, bacteriologists have sought the optimum temperatures for stimulating the growth of various organisms. Four main groups of bacteria have been recognized.¹⁴

The psychrophiles grow below 13.8°C. This group is of interest to the medical profession because it spoils food in cold storage where growth occurs in any moisture which is not actually crystalline.

The mesophiles grow at temperatures comfortable to man. The organisms responsible for fermentation, putrefaction, and decay thrive in the range between 20°C and 30°C. The bacteria causing disease in warm-blooded animals show optimum growth between 37°C and 40°C.

Thermophilic bacteria grow best between 55°C and 80°C and are found in nature wherever warm conditions exist as in warm soils, manure piles, or hot springs. These organisms are of interest because they frequently contaminate laboratory glassware and cause waste in the canning and dairy industries. In the latter, for instance, thermophiles may grow rapidly in a pasteurizer and spoil the quality of the milk.

Thermoduric bacteria survive prolonged exposure to heat and proliferate when ordinary temperatures are again restored. They also are troublesome in the canning and dairy industries.

Heat has long been used unwittingly for the destruction of bacterial life. Since the development of bacteriology, much

⁷ TOPLEY W. W. C. and WILSON G. S. *Principles of Bacteriology and Immunity*. Baltimore: William Wood and Co., 1937 p. 92.

⁸ POOLEY A. T., ODELL T. H. and EDDY C. E. Action of X-rays on Certain Bacteria, *Proc. Roy. Soc., London S. B.*, 118:276-298 August, 1935.

⁹ CHAMBERS, L. A. and GADNER, N. Some Effects of Intense Audible Sound on Living Organisms and Cells, *J. Cell. & Comp. Physiol.*, 1:451-473, 1932.

¹⁰ BACKWITZ, T. D. and OLSON A. R. Ultrasonic Radiation and Yeast Cells, *Proc. Soc. Exper. Biol. & Med.*, 29:362-364 1931-1932.

¹¹ LARSON W. P., HARTZELL, T. B. and DIEHL, H. S.. The Effect of High Pressures on Bacteria, *J. Inf. Dis.*, 22:271 1918.

¹² HADEN, R. B. The Effect of Freezing on Bacteria, *Proc. Roy. Soc., London S. B.*, 124:451-463 1938.

¹³ ALLEN F. M. Reduced Temperatures in Surgery of Limbs, *Am. J. Surg.*, 52:225-237 1941.

¹⁴ McCULLOCH, E. C. *Disinfection and Sterilization*, Philadelphia. Lea & Febiger 1936, p. 82.

research has been done on the bactericidal effect of heat. Unfortunately, specific problems prompted investigators to use different conditions for testing and culturing bacteria, so that the literature is apparently controversial. Accurate data are essential because many problems in sterilization cannot be solved simply by subjecting the material to an abundance of heat.¹⁵ In the sterilization of canned beans, for example, it is imperative to destroy the spores of the deadly *Clostridium botulinum* but an excess of heat results in bean soup rather than appetizing, firm, green beans.

The mechanism of the thermal destruction of bacterial life is poorly understood. One school maintains that heat inactivates vital enzymes in the organism or in the media in which they grow. The fact that spores are more resistant to heat than vegetative bacteria lends support to this theory because the metabolic activity of spores is almost nil. The vital enzymes apparently are combined with the cell proteins in a spore which makes them inactive and more resistant toward heat.^{16, 17}

Others believe that the phenomena of thermal destruction of cells parallel the heat coagulation of proteins so closely that similar processes act. They conclude that death is caused by the heat denaturation of the proteins which make up the bacterial cell. In support, there is the fact that the death rate of bacteria increases suddenly after critical temperatures are reached. Even slight shifts in the hydrogen-ion concentration of the medium in which the bacteria are exposed to heat increase the

death rate just as they influence the coagulation of protein. Like protein, bacteria resist exposure to heat better when dry than when moist.^{18, 19}

Disruption of the cell membrane by heat is also held responsible for thermal death of bacteria.^{20, 21}

It is obvious that actual charring of organisms, as by the cautery, is destructive of bacterial life.

FACTORS INFLUENCING THE THERMAL RESISTANCE OF BACTERIA

Bacteria vary greatly in their resistance to heat. The age of the bacterial cell has marked effect.²² Cultures which are twenty-four to thirty-six hours old survive heating longest. Spores are more resistant than vegetative organisms, thus some organisms have two distinct sterilization periods: that for vegetative cells and that for spores.

Dry organisms are more resistant to heat than wet organisms, therefore, the lethal effects of dry, in contradistinction to moist, heat must be considered. When conducting sterility tests, dry spores rather than wet suspensions of spores should be used. The coagulation of various concentrations of egg albumen affords an interesting parallel. The temperature at which solutions of egg albumen coagulate following a thirty-minute exposure to heat is shown in figure 20.²³

¹⁵ CHICK, H. The Process of Disinfection by Chemical Agencies and Hot Water, *J. Hyg.*, 10, 237, 1910.

¹⁶ CHICK, H. and MARTIN, C. J. On the Heat Coagulation of Protein, *J. Physiol.*, 11, 404-430, 1910.

¹⁷ ECKELMAN, E. VON. Über Bakterien, welche die fraktionierte Sterilisation lebend überdauern. *Centralbl. f. Bakt.*, 48, 140, 1918.

¹⁸ BURKE, G. S. Studies on the Thermal Death Time of Spores of *Clostridium Botulinum*, *J. Infect. Dis.*, 33, 274-284, 1923.

¹⁹ CHICK, H. *The Theory of Disinfection: A System of Bacteriology*. London: Medical Research Council, 1, 178, 1930.

¹⁵ BALL, C. O. Thermal Process Time for Canned Foods, *Bull. Natl. Res. Council*, 7, 1, #37, 1923.

¹⁶ VIRTANEN, A. I. and TARNANEN, J. Die Sekretion und Thermostabilität der Bakterienproteinasen. *Ztschr. f. Phys. Chem.*, 204, 247-258, 1932.

¹⁷ VIRTANEN, A. I. On Enzymes of Bacteria and Bacterial Metabolism, *J. Bact.*, 28, 447-460, 1934.

When moisture is present, coagulation occurs at relatively low temperatures but higher temperatures are necessary when less water is present.

The hydrogen ion concentration of the sterilizing fluid influences the bactericidal effect. In home canning, for example, acid foods can be sterilized readily, whereas alkaline foods are dangerous because the spores of *Clostridium botulinum* are not destroyed unless special precautions are taken.

The individual characteristics of organisms determine their thermal resistance. For example, the various strains of the *Neisseria gonorrhoeae* have characteristic thermal death times ranging from six to thirty six hours' exposure to moist heat at 41.5°C. The average exposure is twelve to fifteen hours.

ESSENTIALS FOR STERILIZATION BY HEAT

In summary, there are three well recognized essentials for sterilization by heat.

1. Bacteria must be heated long enough. A prevalent misleading conception is that a certain temperature is lethal to organisms regardless of the period of exposure and that lesser temperatures are innocuous. When a culture of viable organisms is exposed to an unfavorable environment, the population decreases in an orderly manner. The more noxious the environment, the more rapid the decrease but exposure must be long enough to kill the last "die-hards." Unless this period of exposure to heat is known, a statement regarding the thermal death point has no significance.

2. Bacteria must be exposed to a sufficiently high temperature to destroy them all

* LEWTH, S. Ueber die Ursache der Widerstandsfähigkeit der Sporen gegen hohe Temperaturen. Ein Beitrag zur Theorie der Desinfection, *Arch. f. exper. Path. u. Pharmacol.*, 26:341-354 1889-90

MOISTURE AIDS COAGULATION OF PROTEIN

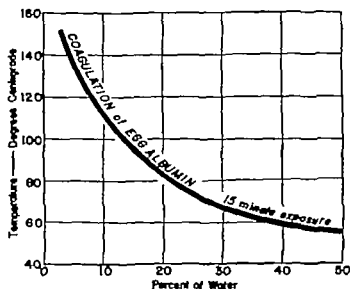


FIGURE 20 Lewth, & Walter*

during the chosen period. The temperature of the least accessible organism is of paramount importance, not that of the sterilizer.

3. The amount of moisture present must be known, otherwise it is impossible to select either a period of exposure or degree of temperature without resorting to an unwarranted abundance of heat.

Several examples illustrate the application of these essentials in medicine. Fever therapy is effective for the differential destruction of bacteria in living patients. A nice application is the treatment of chronic gonorrhea where it is possible to culture the gonococcus and determine its exact thermal death time at 41.5°C. When artificial fever is induced in a patient for that period, the living tissues can be sterilized of gonococci, whereas intervals shorter than the predetermined death time are ineffective.²³

* Walter C. W., "Sterilization of Drawings and Dry Goods," *Int. Abstr. Surg.* 71:414 1940 in *Surg. Gynec. & Obst.*, November 1940. By permission of *Surgery, Gynecology & Obstetrics*.

* WARREN S. L., SCOTT W. W. and CARPENTER, C. M. Artificially Induced Fever for Treatment of Gonococcal Infections in the Male, *J.A.M.A.*, 109 1430-1434 1937.

The pasteurization of milk is another example. The bacteria of milk-borne diseases are readily destroyed by moderate exposure to moist heat of 61.5°C for thirty minutes, yet even slight overheating will spoil the quality of the milk.

THE USE OF HEAT AS A GERMICIDE IN SURGERY

The chief methods of sterilization by heat utilize three forms: moist heat, dry

heat, and actual destruction by charring.

The most universally used methods depend on moist heat. The chief pitfalls in the method are factors which keep moisture from bacteria and prevent sterilization. Improper application of heat, the presence of air, oil and grease, and protein militate against sterilization. The application of these methods is discussed in subsequent chapters.

CHAPTER VI

SANITIZATION BY BOILING WATER

The regulations made in some hospitals that every visitor must sign his name in a book declaring that he has not for a week visited any case of infectious disease or attended a post-mortem examination, before being admitted into the operating room, has always seemed to me to be meant for a sort of plaisanterie. For my own part, when a case goes wrong after an operation, I have seldom to look far beyond myself for the cause of failure — something done something not done. This is a lesson hard to learn we blame persons, things, accidents, and circumstances rather than ourselves

— THOMAS KEITH, 1878 ¹

Since Hugo Davidson, in 1888,² justified the use of boiling water as a germicide because it was readily available, it has been used for the control of disease in hospitals. All types of boiling water sterilizers have certain limitations inherent in the use of boiling water, the chief one being that the boiling point varies with barometric pressure, the maximum being 100.8°C at sea level with a high barometer, a minimum being 84.3°C at Denver with a low barometer.³ This range of temperature has long been recognized as being suitable for sanitation, the destruction of vegetative organisms only, in contrast to sterilization which implies the destruction of all bacterial life. The spores of tetanus and gas gangrene organisms resist short periods of boiling, others survive continuous boiling for forty five hours.⁴

The period of exposure to boiling water

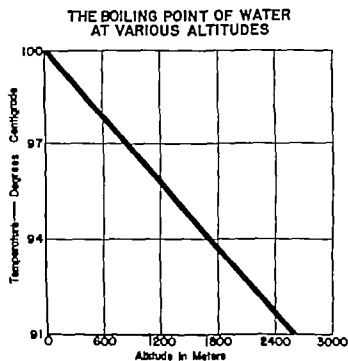


FIGURE 21

varies with the altitude. For altitudes above 300 meters, the period should be increased 20% for each additional 300 meters because the boiling point of the water decreases enough to influence its germicidal effect, figure 21

¹ KEITH, T. Ovariectomy before and after antisepsis, *Br. M. J.*, 2:590 1878.

² DAVIDSON, H. Wie soll der Arzt seine Instrumente desinficiren? *Berl. Klin. Wochenschr.* 25:697 1888

³ Data Courtesy of United States Department of Commerce, Weather Bureau, Denver & Boston.

ENTY, J. R. and MEYER, K. F. The Heat Resistance of the Spores of *B. Botulinus* and Allied Anaerobes, *J. Infect. Dis.*, 31:650 1922.

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—THOMAS KENTH, 1878¹

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The period of exposure to boiling water

¹ KENTH, T. Ovariectomy before and after antiseptics, *Brit. M. J.*, 2:590 1878.

² DAVIDSON H. Wie soll der Arzt seine Instrumente desinficiren? *Berl. Klin. Wochenschr.*, 25:677 1888.

³ Data Courtesy of United States Department of Commerce, Weather Bureau, Denver & Boston.

THE BOILING POINT OF WATER
AT VARIOUS ALTITUDES

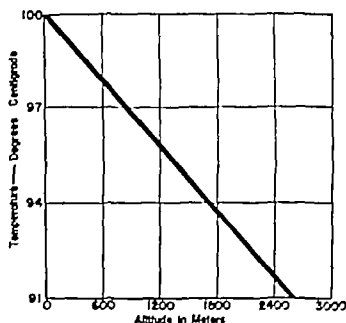


FIGURE 21

varies with the altitude. For altitudes above 300 meters, the period should be increased 20% for each additional 300 meters because the boiling point of the water decreases enough to influence its germicidal effect, figure 21

⁴ Erry J. R. and Meyer K. P. The Heat Resistance of the Spores of *B. pasteurii* and Allied Anaerobes, *J. Infect. Dis.*, 31:650 1922.

As convenience caused the evolution of boiling-water sterilizers from the fish kettle to modern, built-in, "nonpressure" sterilizers, various factors limiting the effectiveness or safety of these sterilizers were recognized. It was found that the sterile contents of a sterilizer could be contaminated by way of its plumbing connections, and vice versa, the water supply might be contaminated from a polluted sterilizer. A technic for avoiding such misfortunes has been elaborated and these precautions are known as "sanitary plumbing" ^{5, 6, 7}

Mechanisms for the pollution of the water supply are illustrated in figure 22.⁸ Continual pressure from the water main is necessary to maintain a column of water in the risers supplying water outlets on the upper floors of a building. Whenever the pressure in the water main decreases, the column of water in the riser is no longer supported and it falls, creating an area of negative pressure at the top of the column. If the riser is taller than 10.3 meters, and if the dynamic pressure in the main falls to zero gage pressure, the water column falls and a vacuum exists above the 10.3 meters level. A common way of causing such a reduction of pressure is to shut off the water supply valve while making repairs. Water trickles through the bubbler or other open faucet, figure 22, 1, and causes the formation of a vacuum in the riser above it. Leaky water faucets or valves on the floor above make this condition dangerous bac-

teriologically, because the negative pressure in the riser is relieved by aspirating fluid backward through the leak. If the aspirated water or air is sterile, the riser is uncontaminated, but if fluid is aspirated from an improperly designed or installed water closet, bedpan hopper, sterilizer or bath tub, the water supply is immediately contaminated with potentially dangerous fluid.

Another manner in which such contamination may occur is illustrated in figure 22, 2. Here, laundry machinery located in the basement of the hospital makes a disproportionately large demand on the water supply which is too small to supply both the laundry machinery, through its wide open valve, and support the column of water in the riser. Hence, every time the valves to the laundry machine are opened, negative pressure is developed in the riser and contamination may occur whenever a water faucet is opened or a faultily designed toilet is flushed on the upper floors. A leaky valve on sterilizing equipment may be a hazard under these conditions.

A leaky water supply valve on a sterilizer is also a menace to aseptic technic because it may permit unsterile water to dribble continually into a sterilizer, figure 23, 1, the contents of which have been sterilized. To protect both the water supply and the sterilizer, an air break illustrated in figure 23, 2, 3, can be interposed between the sterilizer and the water supply. Negative pressure in the riser is overcome by air rushing in through the air break. Leakage past the valve is carried away through a by-pass which has sufficient capacity so that leakage of 160 liters of water per hour is diverted harmlessly into the drain, figure 23, 2. In another type, water is admitted through a series of baffles which lead a small trickle of water into the drain. Leakage follows this course. To fill the sterilizer, sufficient water must be admitted to exceed the

⁵ CONNOLLY, J. I. The Part of Plumbing in Preserving Water Purity, *Armour Eng & Alumnus*, 6 11, October, 1940

⁶ Sanitary Dangers of Cross Connections in Plumbing — An Editorial, *J A M A*, 127 712, 1945

⁷ BURKE, O. J. When Water Runs up Hill — Look Out! *The Ladle*, July, 1943

⁸ KALINSKE, A. A. and KING, F. R. Why Take a Chance? — Hospital Plumbing, *Mod Hosp*, 48 100, March, 1937. By permission of Modern Hospital Publishing Co

MECHANISMS FOR POLLUTION OF WATER SUPPLY

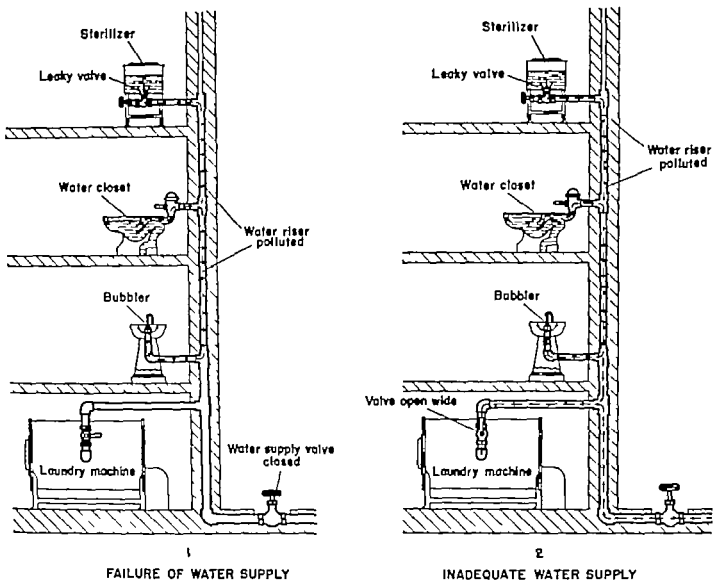


FIGURE 22

Kalinski & King®

SAFE WATER SUPPLY

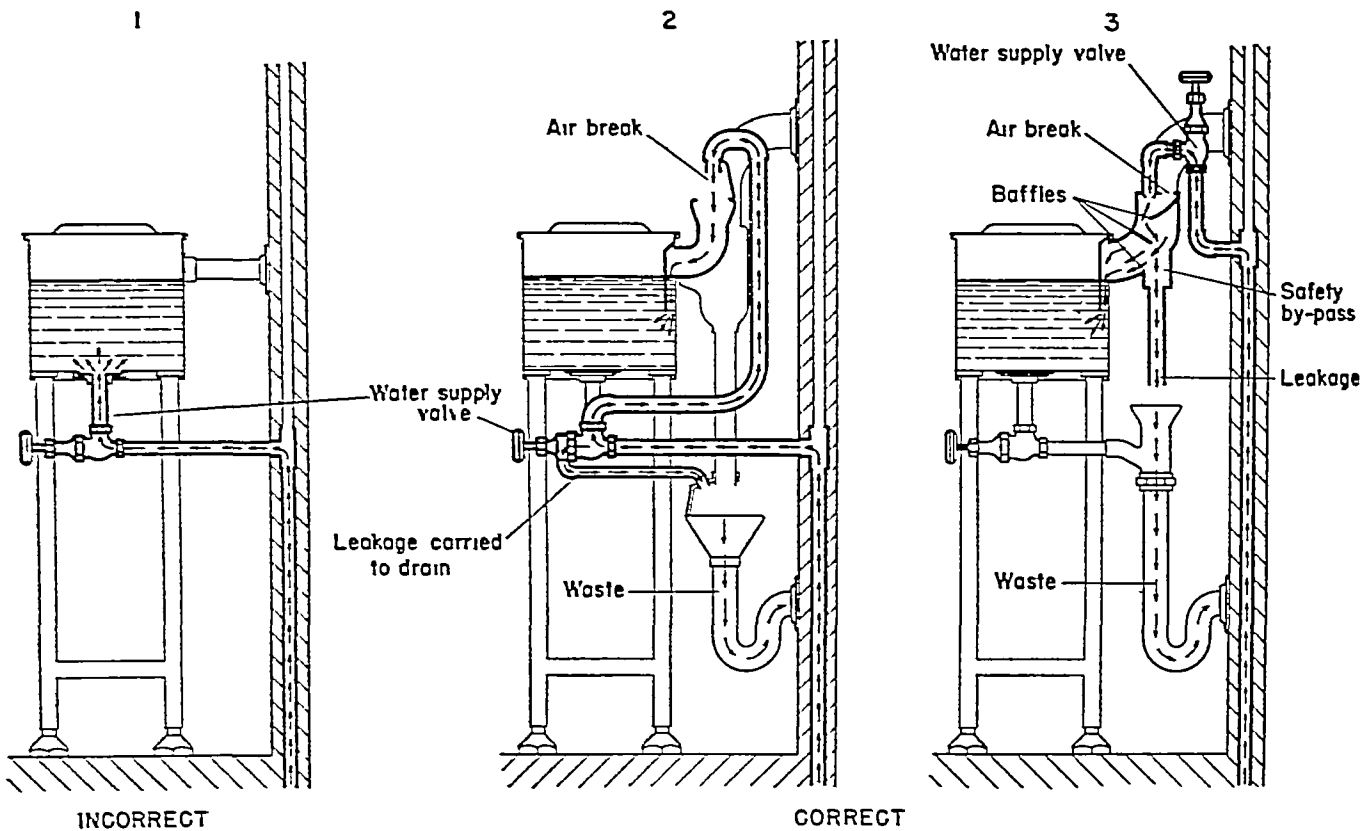


FIGURE 23

PROPER VENT CONNECTION

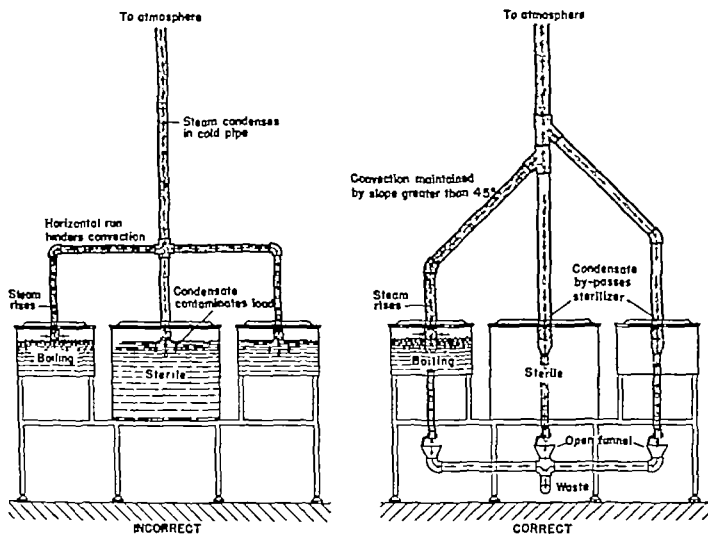
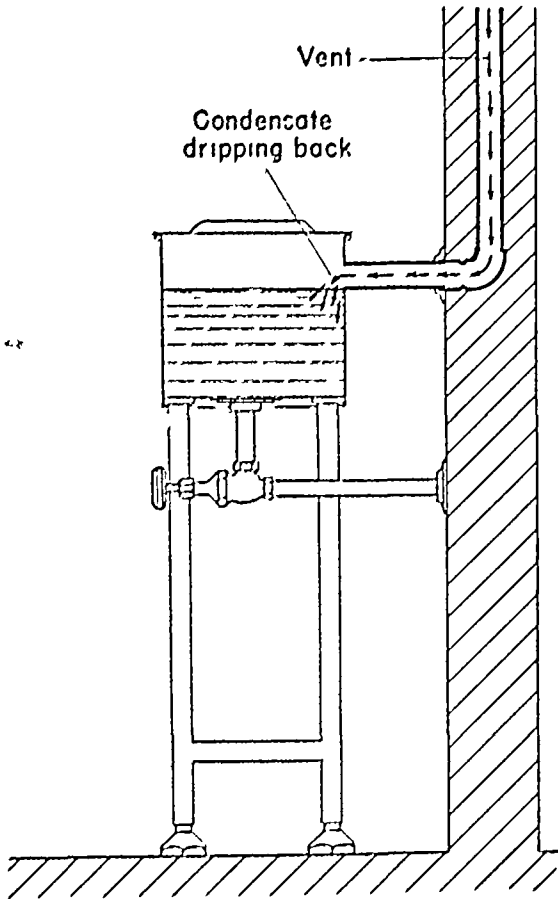
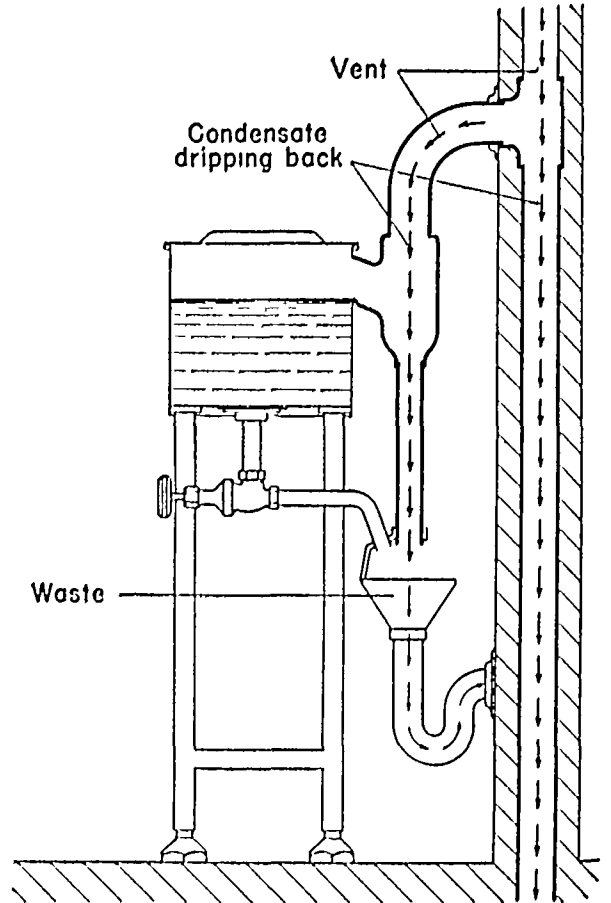


FIGURE 24

SAFE VENT DESIGN



1



2

FIGURE 25

capacity of the safety by pass and spill into the sterilizer, figure 23, 3

To carry away excess steam created by boiling the water in sterilizers, vent lines are often installed to conduct the steam to the atmosphere rather than permit it to fill the room and condense on the walls and ceiling. This not only ruins the decorating but is objectionable because the drip from the moist ceiling frequently contaminates sterile fields. Many vent installations are ineffective because long horizontal runs negate the effect of convection, figure 24. Others are dangerous because as condensation of the steam occurs, the condensate drips back through unsterile vent pipes into sterilizers, figure 25, 1. Properly designed vent connections eliminate this hazard by conducting the condensate to the drain behind a barrier, which prevents it from flowing into the sterilizer, figure 25, 2. Stacks to which sterilizers are vented must not be connected to other plumbing fixtures and should extend to the roof. Measurements essential to safety are given in figure 26.

To avoid the costly installation of vent pipes, automatic vapor control devices are sometimes attached to nonpressure sterilizers. The underlying principle is that steam from the boiling water contacts a thermoresponsive element in the top of the sterilizer which throttles the supply of heat so that the temperature of the sterilizer is kept just below the boiling point. This may be accomplished either by shutting off the main supply of heat and allowing sufficient heat to enter the sterilizer through a by pass of sufficient capacity to maintain sterilizing temperature, figure 27, 1, or by relying upon the throttling action of a special valve to decrease the heat input, figure 27, 2. Electrically heated and gas-fired sterilizers can be equipped with automatic vapor controls.

When properly designed and well ad-

ADEQUATE VENT INSTALLATION

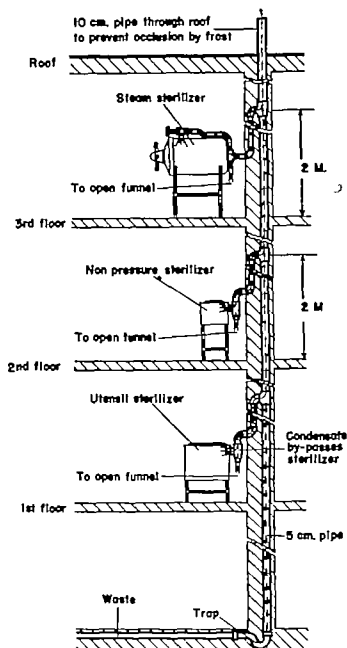


FIGURE 26

justed, these devices are successful but when cheaply made and carelessly maintained, they are dangerous because the temptation exists to adjust them to a temperature sufficiently low so that even an improperly functioning control will eliminate steaming. This is accomplished at the expense of sterilization because the temperature of the water is no longer kept in the neighborhood of 100°C for efficient germicidal effect but dropped below that point for effective vapor

EXCESS VAPOR CONTROL

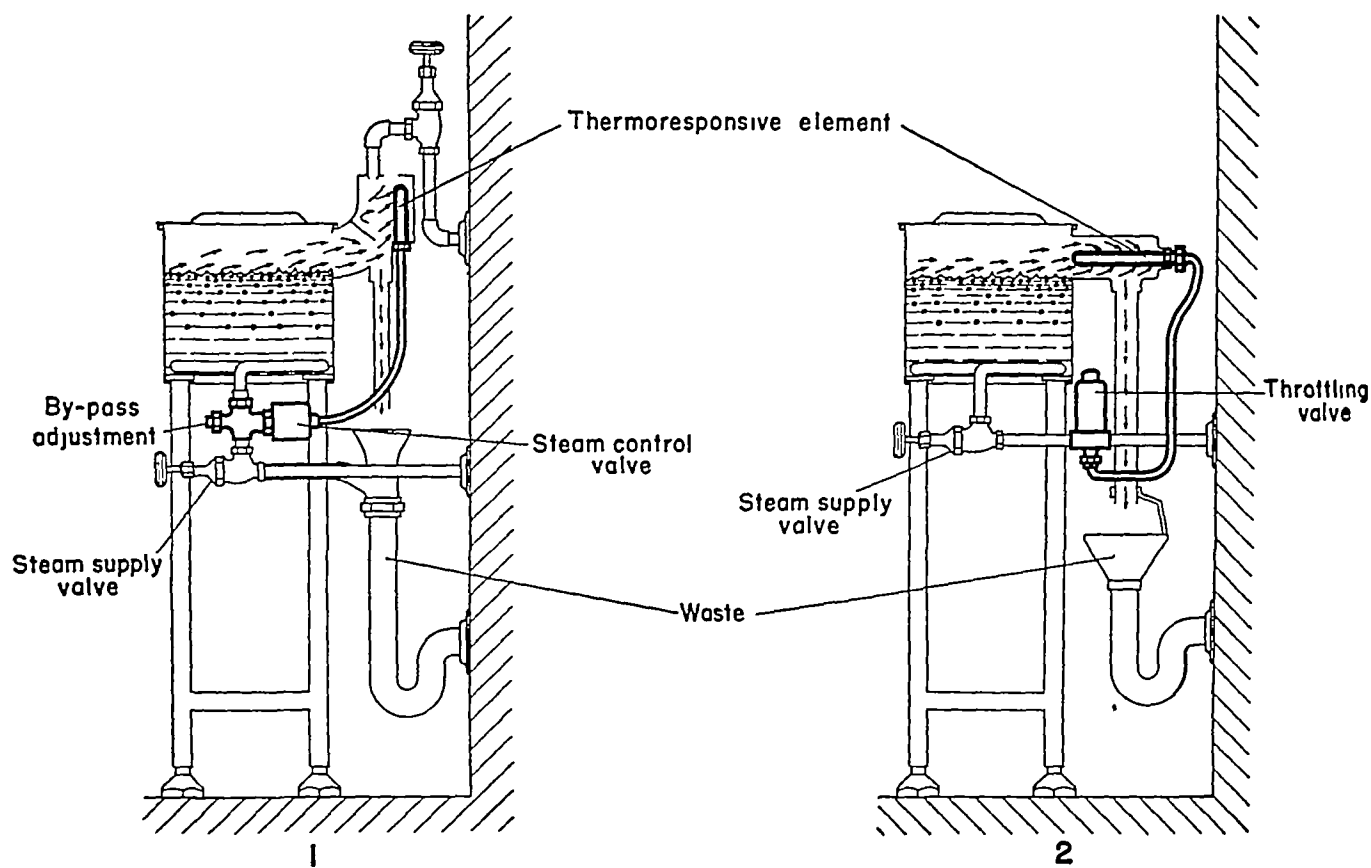


FIGURE 27

PROTECTED WASTE

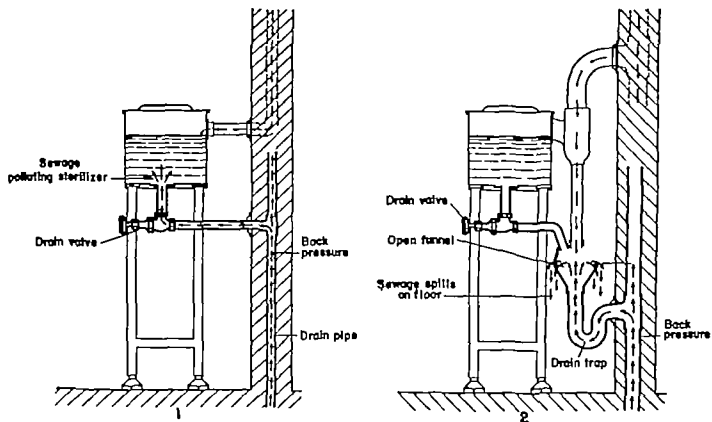


FIGURE 28

control Tampering by uninformed mechanics in the attempt to hasten the action of such controls is one cause for their failure Sterilizers equipped with automatic vapor control devices should be fitted with thermometers also, so that their effectiveness as sterilizers can be checked at will

Contamination of sterilizers by way of the waste line also occurs because sewage backs up, forcing drainage retrograde fashion into the sterilizer through a leaking or open drain valve, figure 28, 1 An air break in the drain line protects the sterilizer against this hazard because sewage spills out of the open funnel, figure 28, 2, and cannot be forced into the sterilizer

The bactericidal efficiency of nonpressure sterilizers can be increased in several ways Everything in the sterilizer must be filled and covered with water to eliminate air pockets An example of faulty sterilization, due to trapped air, occurred in a hospital where the neurological surgeon used a test tube tied to his sterile drapes as a holster for the electrocautery The inside of the test tube was shown to be unsterile Investigation revealed that it frequently floated bottom side up in the water, figure 29, trapping air which protected dry bacteria in the bottom of the test tube from the destructive action of moist heat

The addition of alkali is an advantageous way of increasing bactericidal efficiency by lowering the hydrogen-ion concentration⁹ It also decreases the corrosive action of boiling water on instruments¹⁰ The addition of sufficient sodium carbonate (sal soda) to make a 2% solution in the sterilizer or sodium hydroxide (lye) to make a 0.1%

⁹ ECKER, E. E. and SMITH, R. Sterilizing Surgical Instruments and Utensils, *Mod Hosp*, 48:92, March, 1937

¹⁰ SCHIMMELBUSCH, C. Die Durchführung der Asepsis in der Klinik des Herrn Geheimrath von Bergmann in Berlin, *Arch f klin Chir*, 42:123, 1891

TRAPPED AIR PROTECTS BACTERIA

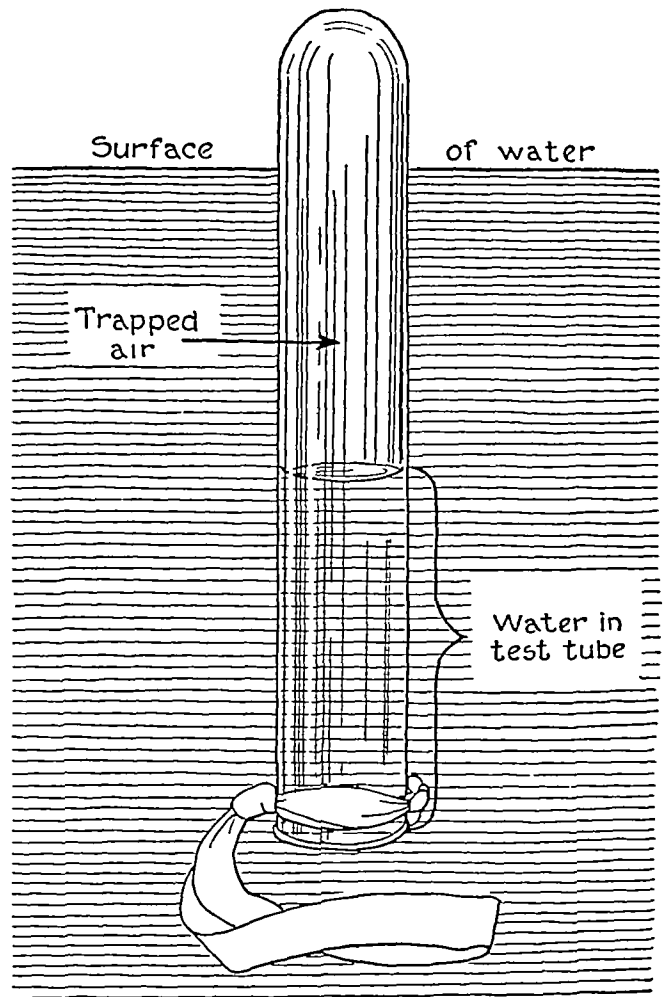


FIGURE 29

solution should be adopted widely in the interests of economy and safety

In areas where hard water is encountered, a water softener should be added to sterilizers to prevent the deposition of lime salts as a scale on instruments and the inside of the sterilizer The quantity and kind of softener to be added must be determined for each local water supply

Oil and grease must be kept out of non-pressure sterilizers because these substances prevent moist heat from contacting bacteria and protect them against sterilization The greasy ring often found at the water level on the inside of sterilizers indicates gross carelessness and disregard for the safety of the patient

Instruments must be opened or unlocked so that no metal surfaces are held in such tight mechanical apposition that water can not wet all surfaces of the instrument. Whenever moisture is excluded, germicidal action is dependent upon dry heat and the temperature of boiling water is too low to be effective.

The safe minimum period for sterilization in boiling water at altitudes less than 300 meters is thirty minutes at 100°C for vegetative organisms. If the hydrogen ion concentration is decreased by the addi-

tion of alkali, the period of exposure can be safely decreased to fifteen minutes.^{9 11 12} The fifteen minute period is adequate for the destruction of certain spores, provided the pH is carefully controlled. At higher altitudes, the sterilizing period must be increased.

Boiling water is an inadequate germicide for preoperative sterilization and should not be used where steam is available.

¹¹ SOBERNHEIM, G. Ueber Instrumentensterilisierung. *Science und Wochschr.*, 62 1034 1932.

¹² WALBURN, L. E. Sterilization of Surgical Instruments, *Hosp. Tid.*, 76 57 January 1933.

CHAPTER VII

STERILIZATION BY STEAM

To reduce human errors to a minimum it is absolutely essential that both those who are in charge of sterilization, as well as those who actually carry it out, should at first be amply qualified and should then be regarded as fixed staff.

— WALTER E. DANDY, 1932 ¹

FLOWING STEAM

Flowing steam at atmospheric pressure is occasionally used as a germicide. The Arnold Sterilizer is the common type of equipment used for the purpose. Originally, this method was designed for the cooking of vegetables without immersing them in

water ² It was early adapted to sterilization of hospital supplies and is still used in remote places. As shown in figure 30, it consists of a steam generator fed drop-wise from a reservoir. The steam rises upward through the sterilizing chamber and escapes through the loosely fitted door into a jacket

ARNOLD STERILIZER

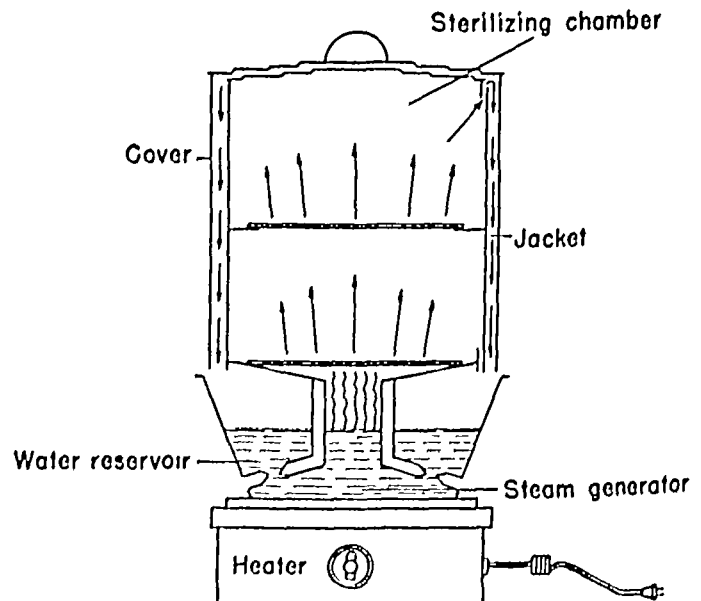
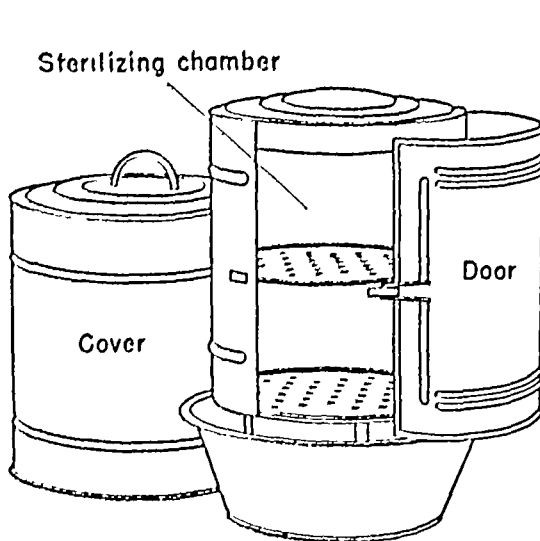


FIGURE 30

¹ DANDY, W. L. Importance of More Adequate Sterilization Processes in Hospitals, *Bull Am Coll Surg*, 16 11, 1932

² MAGATH, T. B. The History of Steam Sterilization, *Ann Med Hist*, 9 338-344, 1937

EQUIPMENT FOR USE OF SATURATED STEAM UNDER PRESSURE

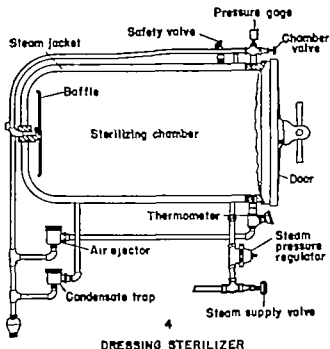
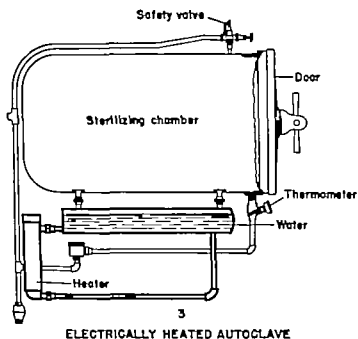
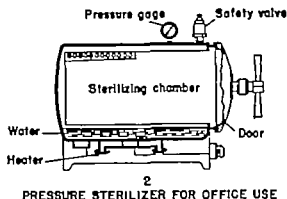
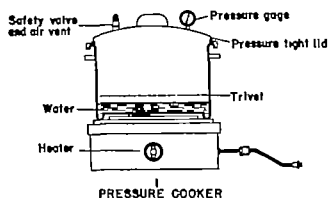


FIGURE 31

formed by the cover. Here, it condenses and the condensate drips back into the reservoir.

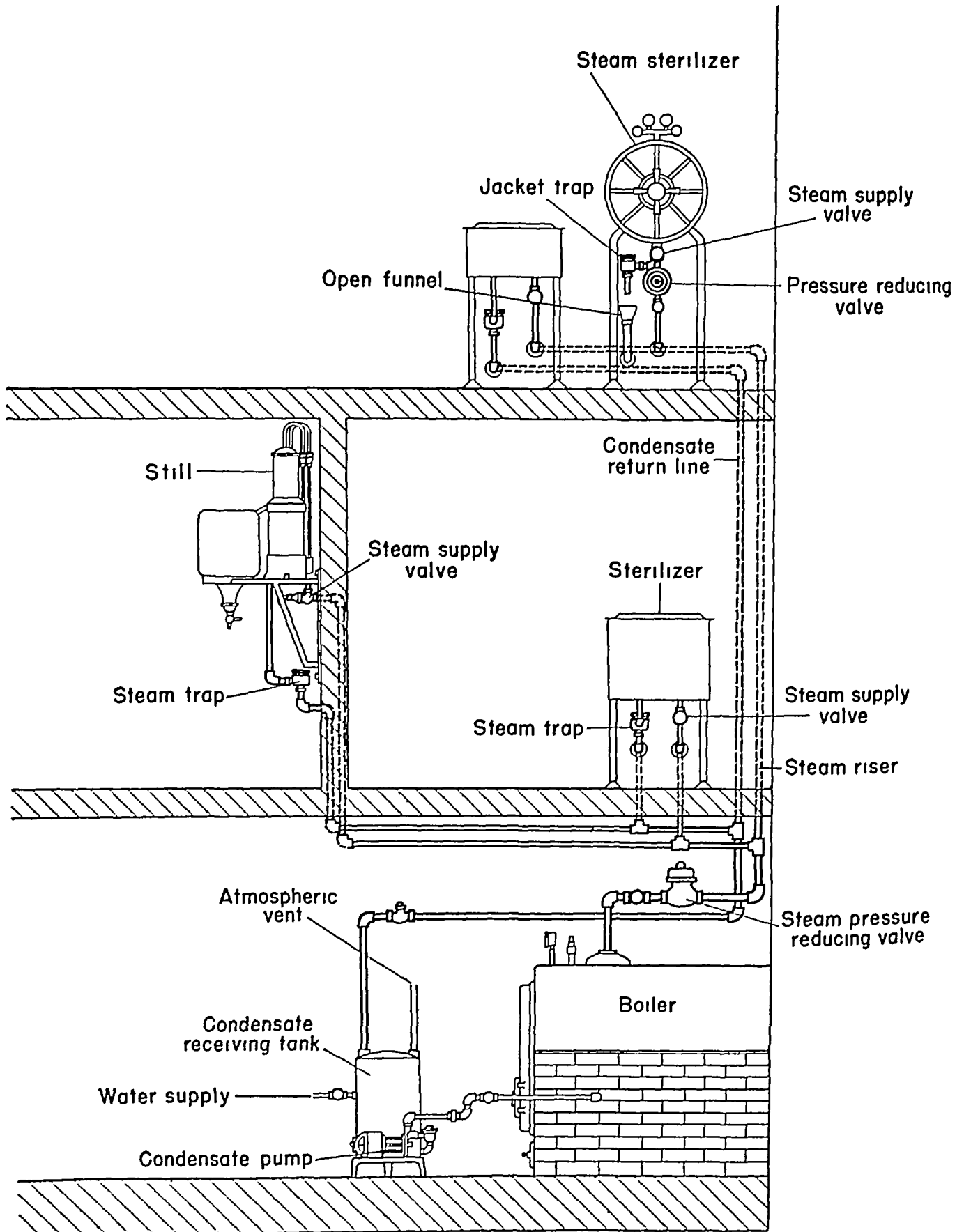
Flowing steam has the limitations inherent in the use of boiling water. The maximum temperature attainable is 100°C and, accordingly, it destroys vegetative organisms only. Unless skillfully used, textiles are excessively moist when removed from an Arnold Sterilizer. It is suitable for the disinfection only of small packages because the quantity of steam available is usually too small to permit the prompt penetration of large packages. The minimum period

for sanitization is thirty minutes' exposure after the condensate drips from the jacket.

SANITIZATION BY WATER VAPOR

Commercial processors sometimes utilize steam under pressures less than atmospheric to sanitize products likely to be injured by heat. The technic calls for vacuum equipment capable of removing most of the air and a means for admitting water vapor under carefully controlled pressure. The process is comparable to pasteurization in the period of exposure and temperature used. Superheating must be guarded against

CENTRAL STEAM SUPPLY



VAPOR PRESSURE CURVE FOR WATER

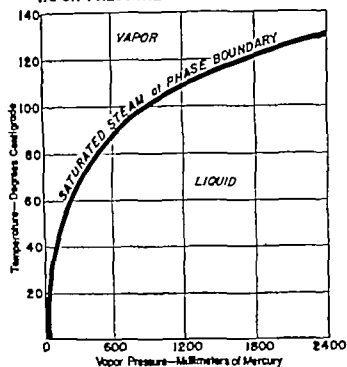


FIGURE 33

because it robs the steam of its bactericidal properties. Clothing, bedding, shoes, and the like are sanitized by this technic in some hospitals for communicable disease.

SATURATED STEAM UNDER PRESSURE

Saturated steam under pressure has become the universal germicide for textiles. Special equipment is necessary for its successful use. The autoclave and the "pressure sterilizer" or dressing sterilizer are types of equipment which have been developed to use saturated steam. The autoclave is simply a pressure tight vessel, usually upright, in which steam can be generated under pressure. The pressure cooker is a good example, figure 31, 7. Heat is applied to the outside of the cooker by means of an electric, gas, or oil heater and it generates steam from a small quantity of water, initially put below the trivet. "Flexseal" and "Presto" are trade names of domestic cookers that can be used as sterilizers.

The office sterilizer illustrated in figure 31, 2, is an adaptation of the pressure

WETTING EFFECT OF SATURATED STEAM

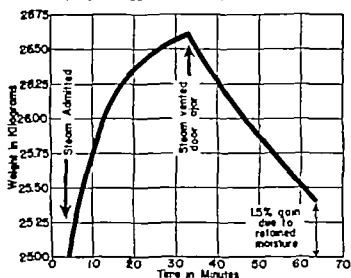


FIGURE 34

Walter

cooker. Heat is applied directly to the sterilizer. Figure 31, 3, shows a type of pressure sterilizer where the heat is applied remotely and the steam carries the energy to the sterilizer. Figure 31, 4, shows a dressing sterilizer where the steam is generated in a boiler, usually in the basement, figure 32. The steam is first introduced into the jacket to heat the chamber walls and thus prevent condensation on the inner wall of the sterilizing chamber.

Several factors have established saturated steam as a reliable microbicide. It is a physical entity with properties which can be measured readily. Anyone can determine the microbicidal quality of the steam in a sterilizer merely by reading a thermometer and a pressure gage. The term "saturated steam" means that the steam exerts the maximum pressure for water vapor at the given temperature. The steam, therefore, is in a state lying on the boundary between two phases of aggregation, liquid (water) and vapor (steam), figure 33.¹ The shift from one state to the other entails a rela-

¹ PEARSON, C. H. *Tables of Properties of Steam and Other Vapors and Temperature Entropy Tables*. New York, John Wiley and Sons, 1910 8th Edition.

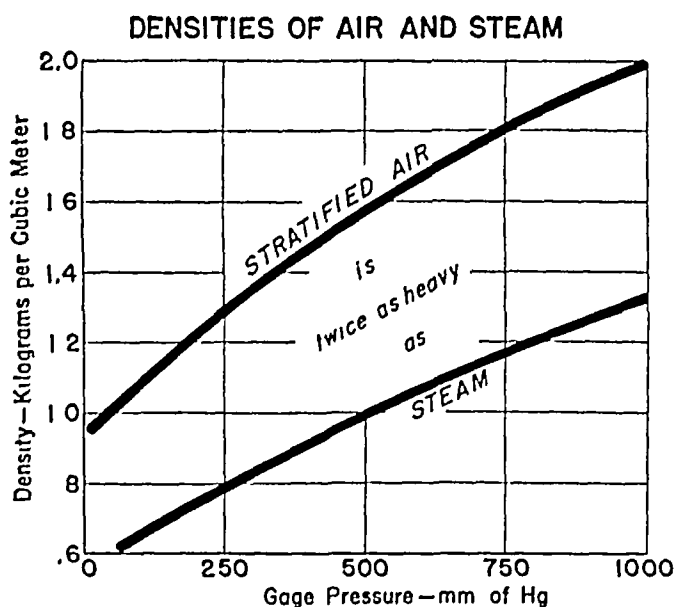


FIGURE 35

Walter⁴

tively large exchange of energy. In the range of temperatures and pressures ordinarily used for sterilization, 524 gram calories of energy must be exchanged for every cubic centimeter of water taking part in the change of state.

The readily available store of latent energy which is liberated simply by a shift in state is of enormous advantage to a microbicide because it permits rapid heating without a drop in temperature locally. On contacting cold objects, saturated steam condenses, simultaneously heating the object and wetting it, providing both requisites for thermal destruction of bacterial life — moisture and heat.

The wetting effect is well illustrated by figure 34 which shows a 6% increase in weight of three laparotomy kits due to condensate which is deposited as they are heated from room temperature to sterilizing temperature by saturated steam at 121°C. The data were obtained on a recording scale from which the bundles were suspended in a sterilizer during routine

sterilization. The water of condensation moistens the textile fibers and the bacteria and permits sterilization at relatively low temperatures. Steam sterilization is often thought of as a dry process because the fabric is dry when removed from the sterilizer. The reason for this is illustrated also. When the steam is released from the sterilizing chamber, the water of condensation in the textile evaporates, leaving a residual of but 1.5% after thirty minutes. Much of this drying effect is due to the fact that the condensate and the textiles are at 121°C under 1500 mm Hg pressure when the latter is reduced to atmospheric pressure by venting the steam. This sudden drop in pressure forces the condensate to vaporize until sufficient energy is dissipated to cool the textile to 100°C where water can exist in equilibrium with vapor at atmospheric pressure. The dehydrating effect due to vaporization caused by relieving pressure can be followed on the vapor pressure curve for water, figure 33.

Saturated steam penetrates textiles readily for two reasons:

1. Steam is less dense than air. This can be seen from figure 35,³ which illustrates what happens as steam is forced into a closed chamber full of air. Both the steam and air are compressed as the pressure rises and they become more dense. Throughout the compression, the air is approximately twice as heavy as the steam. Mixture does not occur readily and the air stratifies on the bottom of the sterilizing chamber. Steam displaces the cold, heavier air from the interstices of textiles by convection.

2. Abstraction of heat from steam causes a change in its state with a simultaneous 99% decrease in volume. This sudden collapse in volume results in the instantaneous development of local areas of negative pressure at the cold front. These areas hasten penetration because more steam

⁴WALTER, C. W. "A Reliable Control for Steam Sterilization." *Surg. Gynec. & Obst.* 67: 526-530, 1938. By permission of *Surgery, Gynecology & Obstetrics*.

bearing its load of latent heat rushes in to overcome the low pressure, contacts cold surfaces, and in turn condenses. Thus, penetration by steam is a self-perpetuating process which continues as long as steam can contact colder objects.

The quantitative aspects of steam sterilization are illustrated in figure 36. The latent energy from 865 cc. of steam is needed to heat a size seven surgeon's glove weighing 13.6 grams to sterilizing temperature. As the steam contacts the cold glove, it condenses to form 1 cc of water which wets the surface of the glove. The other 864 cc. of space previously occupied by the steam are momentarily empty and are instantly refilled by more steam. Figure 34 considers the process as static for purposes of illustration, in reality, it is progressive. The collapse in volume at any instant is minute but none the less effective.

Saturated steam destroys dry resistant spores upon relatively short exposure. The actual period necessary depends upon the temperature of the steam as portrayed in figure 37.¹ Raising the temperature markedly decreases the exposure required. Several temperatures have come into common

QUANTITATIVE ASPECTS OF STEAM STERILIZATION

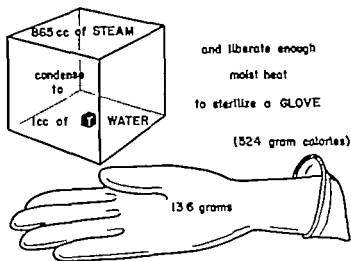


FIGURE 36 *Walter²²*

usage. Saturated steam under 750 mm. Hg gage pressure with a temperature of 121°C is the most widely used microbicide. It destroys most resistant dry spores in thirteen minutes.²⁻²³

Saturated steam at 128°C and 1150 mm. Hg gage pressure is used in some hospitals under the mistaken idea that an abundance

¹ BROOKLOW W D. The Logarithmic Nature of Thermal Death Time Curves, *J. Infect. Dis.*, 29:528-536, 1921

² GLOMB, M. Kartoffelbacillus mit ungewöhnlich widerstandsfähigen Sporen, *Zentralbl. f. Hyg. u. Infektionskr.*, 3:322-332, 1888.

³ MIGUEL, P and LATRAYE, E. De la résistance des spores des bactéries aux températures humides égales et supérieures à 100° *Ann. de microsc.* 7:110 158 and 205 1895

⁴ NITZE, E. Botanische Beschreibung einiger sporenbildenden Bakterien, *Zentralbl. f. Bakt. II Abt.*, 12:1 161 337 539 1904

⁵ BLAU, O. Ueber die Temperaturmaxima der Sporenkeimung und der Sporenbildung, sowie die supraoptimalen Tödtungszeiten der Sporen der Bakterien, auch derjenigen mit hohen Temperaturminima, *Zentralbl. f. Bakt.*, II Abt., 15:97 1905

⁶ SHANKLY E. On the Heat Resistance of Bacterial Spores with a Consideration of the Nature of Spore-like Bodies Seen in *Bacillus Tuberculosis* and Allied Forms, *Proc. Roy. Soc. Canada, Series III* 9:121 1915.

¹¹ BOGHANAN R. E., THOMPSON G. E., ORR, P. F. and BRUETT E. M. Notes on Conditions Which Influence Thermal Death Points, *Abst. Bact.*, 2:5 1918 (Proc. Soc. Amer. Bacteriol.)

¹² DICKEYON E. C., BURKE, G. S. and WARD, E. S. Botulism A Study of the Resistance of the Spores of *Bacillus Botulinus* to Various Sterilizing Agencies Which Are Commonly Employed in the Canning of Fruits and Vegetables, *Arch. Int. Med.* 24:581 1919

¹³ BROOKLOW W D and ESTY J R. The Thermal Death Point in Relation to Time of Typical Thermophilic Organisms, *J. Infect. Dis.*, 27 602, 1920

¹⁴ WESS, H. The Heat Resistance of Spores with Special Reference to the Spores of *B. Botulinus*, *J. Infect. Dis.*, 28 70-92, 1921

¹⁵ DICKEYON E. C., BURKE, G. S., BECK, D., JOHNSON J. and KNOX H. Studies on the Thermal Death Point of Spores of *Clostridium Botulinum*, *J.A.M.A.*, 79 1239-1240, 1922.

¹⁶ TANNER, F. W. and McCREA, F. D. *Clostridium Botulinum*. IV Resistance of Spores to Moist Heat, *J. Bact.*, 8:269-276, 1923

¹⁷ TANNER, F. W. and DACK, G. M. *Clostridium Botulinum*, *J. Infect. Dis.*, 31:92-100 1922.

¹⁸ ESTY J R. Heat Resistance of *B. Botulinus* Spores, *Am. J. Pub. Health*, 13:108-113 1923

THERMAL DEATH TIME OF RESISTANT SPORES

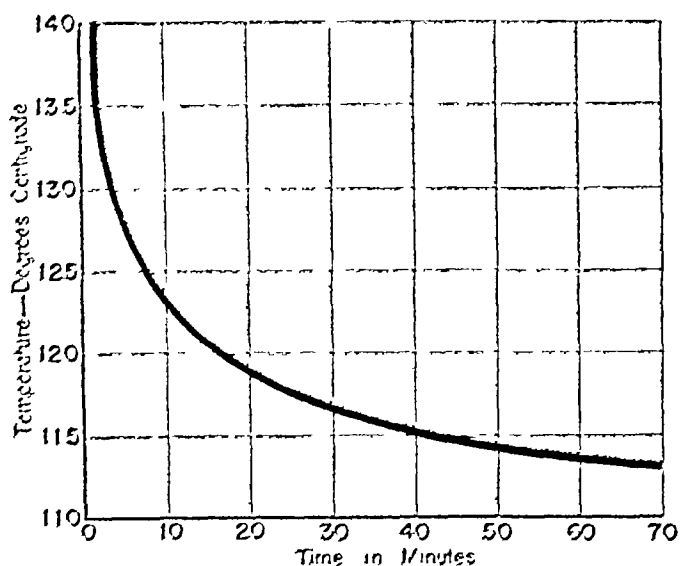


FIGURE 37 Bigelow⁶

of heat is essential for sterilization. The only advantage of steam at this temperature is the shorter lethal period of six minutes. The destructive action of the steam on rubber and textile is enhanced too much to justify this saving in time.

For emergency sterilization of instruments, a short lethal period, two minutes' exposure of the least accessible spore to saturated steam at 132°C under 1400 mm. Hg gage pressure, is advantageous.

One last advantage of saturated steam is that it does not destroy most operating room supplies when it is used properly. In fact, deterioration is not excessive, as is demonstrated for textiles in figure 38.

Despite the outstanding advantages which seem to make saturated steam the ideal microbicide, there are limitations which decrease or nullify its effectiveness.

If a volume of saturated steam in which there is no liquid water is heated, its temperature increases above that characteristic

DETERIORATION OF TEXTILES DUE TO LAUNDERING AND STERILIZATION

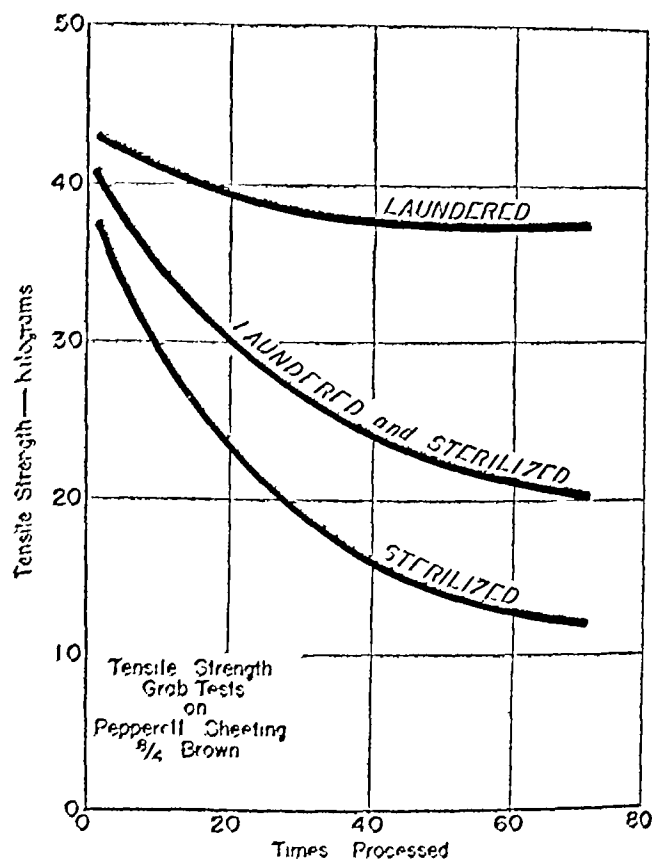


FIGURE 38

of steam at the phase boundary and it is known as superheated steam. In figure 33, superheated steam lies above and to the left of the vapor pressure curve. The difference between saturated steam and superheated steam is striking. When steam is superheated, its microbicidal power is diminished. When superheated sufficiently, it chars textiles. As a microbicide, it differs from saturated steam because it has lost the property of liberating latent energy when

²¹ MURRAY, T. J. Thermal Death Point, Spores of *Bacillus Anthracis*, *J. Infect. Dis.*, 42:457-467, 1931

²² HADLEY, M. R. Thermal Death Point, Spores of *Clostridium Welchii*, *J. Infect. Dis.*, 42:468-483, 1931

²³ VON ESCHERICH, L. Die desinfizierende Wirkung des strömenden überhitzten Dampfes, *Ztschr. f. Hyg. u. Infektionskr.*, 4:197-206, 1882

²⁴ LUDWIG, H. Beiträge zur Desinfektion mit Wasserdampf, *Ztschr. f. Hyg. u. Infektionskr.*, 9:492, 1890-91

²⁵ POKER, M. Zur Theorie der Dampfdesinfektion, *Hyg. Rundschau*, 2:721, 1892

⁶ KROGER, J. Untersuchungen über die Sterilisierung von Verbandstoffen, *Deutsche Ztschr. f. Chir.*, 221:28-39, 1922.

²⁶ MURRAY, T. J. and HADLEY, M. P. Thermal Death Point, Spores of *Clostridium Tetani*, *J. Infect. Dis.*, 42:426-436, 1931.

SUPERHEATED STEAM AS A MICROBICIDE

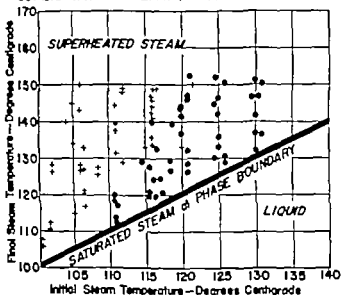


FIGURE 39

Savage²²

it contacts cold objects. Hence superheated steam is no more effective than hot air²²⁻²³ until it cools to the temperature characteristic of saturated steam, at which point it regains its original physical and bactericidal properties.

Figure 39²² presents diagrammatically the effect of superheat on the microbicidal power of steam. The phase boundary is represented as a straight line, while points to the left and above it represent various degrees of superheating. The crosses indicate positive cultures; the dots, negative cultures exposed to superheat of the varying degrees indicated. Note that minor degrees of superheating are not serious from a bacteriologic point of view but, as will be seen later, superheated steam destroys textiles.

One common cause of superheating is the maintenance of a higher pressure, and hence temperature, in the sterilizer jacket than in the chamber. The hotter jacket adds heat to the saturated steam in the chamber driving it away from the liquid vapor boundary

²² SAVAGE, R. M. Experiments on the Sterilizing Effects of Mixtures of Air and Steam and of Superheated Steam, *Quart. J. Pharm. & Pharmacol.*, 10:451, 1937

SUPERHEATING CAUSED BY HOT JACKET

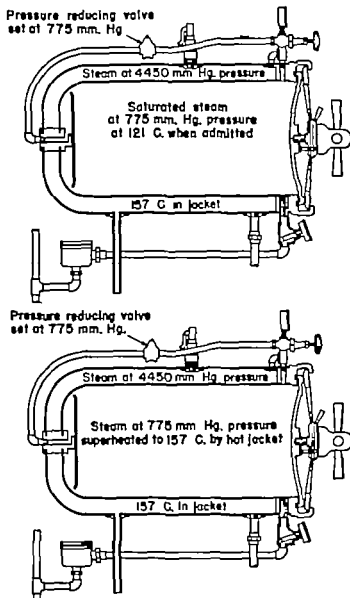


FIGURE 40

and changing its properties. In one hospital, for example, a steam pressure of 4450 mm. Hg gage pressure and 157°C was carried in the jacket, while steam under but 750 mm Hg gage pressure was admitted to the chamber, figure 40. Superheating of 36°C resulted in rapid destruction of textiles of the outer layers of packages, while spores survived in the center, chiefly because of the poor penetrating power of superheated steam.

Superheating also occurs because of the physical properties of textile fibers. As can

ABSORPTION OF WATER BY SODA-BOILED COTTON

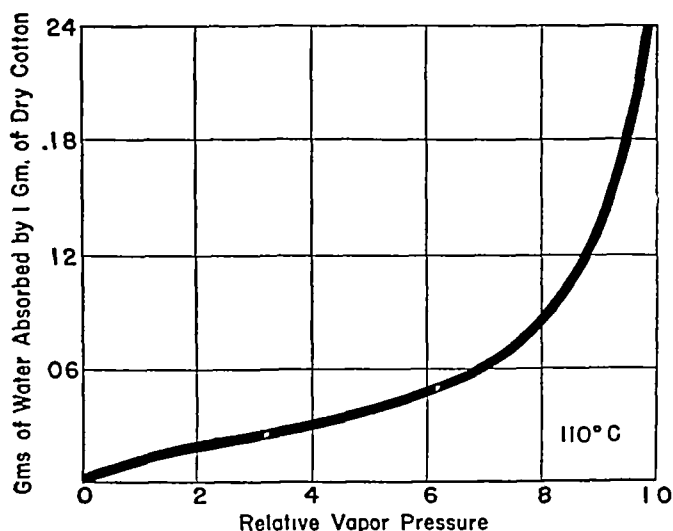


FIGURE 41 *Urquhart & Williams*²⁷

be seen in figure 41,²⁷ textile fibers adsorb moisture. As this moisture is being adsorbed, latent energy is liberated which must be dissipated by heating the environs.

When a laparotomy kit, made up of textiles whose fibers are saturated with moisture, is heated from room temperature to sterilizing temperature, its weight increases roughly 6%. The increase in weight of a laparotomy kit weighing 8.5 Kg is due to the deposition of 5 Kg of water throughout the fabric by condensation of 440 liters of steam which flow into the bundle to heat it. In figure 43, 1, the jug containing 516 cc of water represents in terms of condensate, the energy exchange necessary to heat the bundle to sterilizing temperatures.

Extreme superheating occurs when fibers are "preheated" by putting them in the sterilizing chamber while steam pressure is maintained in the jacket. The fabric is heated to the temperature of the jacket and is also desiccated. When steam is subsequently admitted to the chamber, the

SUPERHEATING OF PREHEATED TEXTILES

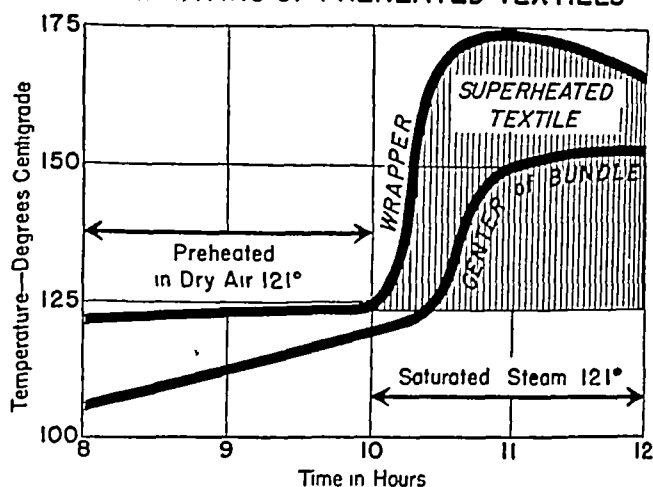


FIGURE 42

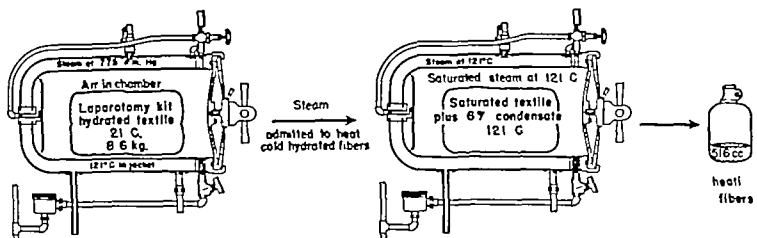
thirsty fibers adsorb water from the steam, liberating latent energy, all of which must be dissipated by superheating the preheated fabric. The temperature of the fabric reaches the charring point and spontaneous combustion may occur when air strikes such fabric upon its removal from the sterilizer.

When a laparotomy kit is preheated, its fibers are desiccated and the energy exchange is no longer determined by the need for heat but rather by the thirst of the fibers. Fibers of textile, which have been laundered repeatedly, may extract 22% of their dry weight of moisture from the steam surrounding the bundle, thus liberating the latent energy from 1.5 Kg of condensate. This is represented in figure 43, 2, by the jug containing 1540 cc of condensate. Because the textiles have been preheated to sterilizing temperature, the excess energy must be dissipated by superheating as shown in figure 42. The charred wrappers seen in almost every operating room are indicative of this fault in sterilization.

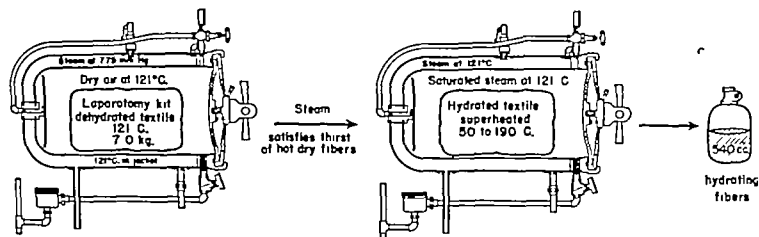
Lesser degrees of superheating are caused by putting anhydrous textiles into the sterilizer. Such fibers may absorb as much as 22% of their dry weight of water and liberate excess latent energy which superheats the textiles. The amount of energy

²⁷ URQUHART, A. R. and WILLIAMS, A. M. The Effect of Temperature on the Absorption of Water by Soda-boiled Cotton, *J. Text. Inst.*, 15 T559, 1924.

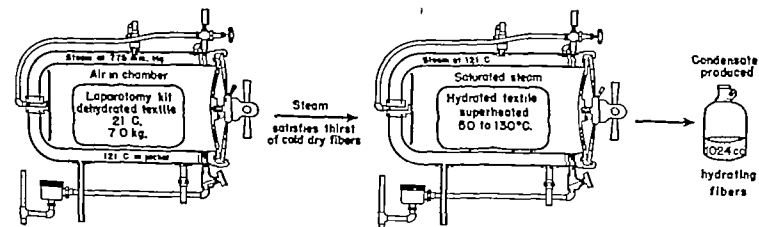
ENERGY EXCHANGE IN TEXTILES IN A STEAM STERILIZER



1 NORMAL STERILIZING CONDITIONS



2. LOAD PREHEATED



3. DEHYDRATED TEXTILE

FIGURE 43

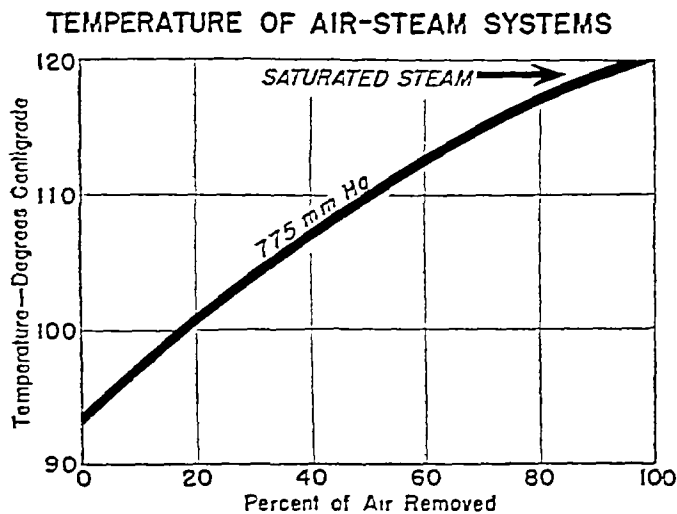


FIGURE 44.

Berry²³

dissipated as superheat is represented as condensate by the 508 cc. difference between 516 cc produced under normal sterilizing conditions and the 1024 cc formed when dehydrated textiles are sterilized, figure 43, 3.

The cumulative effect of such superheating can be demonstrated readily. Identical samples of textiles were sterilized simultaneously twice weekly during the fall and winter months when the humidity in heated rooms is low. Half the samples were laundered along with controls immediately preceding sterilization. The textiles which were laundered (hydrated) immediately prior to sterilization lost 50% of their tensile strength after seventy trips through the laundry and sterilizer, figure 38. Samples which were sterilized repeatedly without laundering (dehydrated by exposure to dry air) lost 73% of their tensile strength. Samples which were laundered only, as controls, lost but 20%. Since 18 Kg. represents the limit of utility for sheeting, the laundered samples have more than twice the life of those that are simply resterilized.

Studies attempting to correlate the loss in tensile strength with the duration of exposure revealed that some deterioration of textile fibers occurred each time the fibers were heated; that prolonged exposure

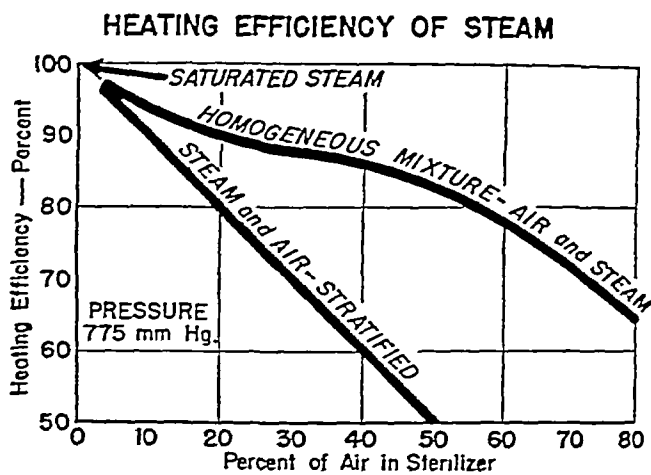


FIGURE 45 Warren Webster Company,²⁹ Walter⁴

damaged the fibers but little more. Using freshly laundered (hydrated) textiles, therefore, is economical because it avoids superheating which causes charring and early destruction.

Another cause for superheating is the technic of drawing an initial partial vacuum to rid the sterilizer of some air. The vacuum itself desiccates the fibers and, in addition, the load is necessarily preheated during the interval while the vacuum is being drawn.

Superheating also results from the custom of heating a load quickly by using steam under 1150 mm Hg gage pressure and then dropping the pressure to 750 mm. Hg gage pressure during the sterilizing period.

A second limitation of saturated steam as a microbicide is that air retards or prevents sterilization in several ways. Air-steam mixtures do not develop the temperatures characteristic of saturated steam under the same pressure, hence, killing power is decreased. This depression of temperature is shown in figure 44²⁸. Even after the removal of one third of the air by drawing a 510 mm vacuum prior to introducing steam under a pressure of 1540 mm Hg, the temperature of the mixture of residual air and steam is but 105°C instead of 121°C.

²⁸ BERRY, C. H. Air and Water Vapor Mixtures. Personal communication, 1939.

PENETRATING POWER—STEAM VERSUS AIR

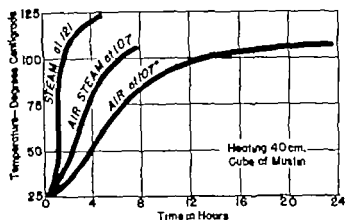


FIGURE 46

Waller⁴

which is characteristic of saturated steam under the same pressure

The heating efficiency of air steam mixtures is lower than that of saturated steam, a fact that is particularly important in the sterilization of instruments or solutions. Figure 45²² shows the efficiency of saturated steam as 100%. As air is introduced into the steam, this efficiency is markedly decreased because the thermal capacity of air is low compared with that of the steam where 81% of its energy at 121°C is in the form of latent heat

Air reduces the penetrating power of steam because it prevents the convection of steam into bundles and the liberation of latent energy in the depths of a bundle.²⁰ In a sterilizer where air is present, heating is principally by conduction. Figure 46 contrasts the power of penetration by steam compared with mixtures of air and steam or hot air alone. The curves were obtained by recording the time and temperature relationship in the center of identical 40 cm. cubes of folded muslin. It took nine hours for the mixture of air and steam usually encountered in an air bound sterilizer to

STRATIFIED AIR PROTECTS BACTERIA

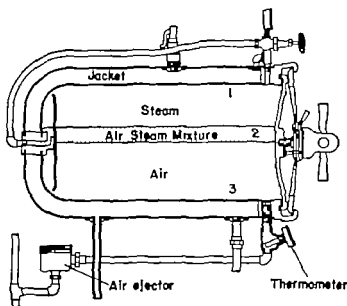


FIGURE 47

Waller²³

heat the bundle to a maximum of 107°C. Hot air at the same temperature heated the test bundle in twenty four hours, while the saturated steam penetrated the cube in only four hours.

Air prevents mechanical contact between steam and bacteria because the air is more dense, it gravitates toward the bottom and effectively protects organisms against sterilization as is shown in the longitudinal section of a sterilizer in figure 47

A third limitation is that oil or grease converts each spore into a miniature dry-air oven by preventing the access of moisture.^{24, 25, 26} These substances, therefore, protect bacteria against the rapid microbicidal action of steam.

A fourth limitation concerns sanitary plumbing, figure 48. Because the steam is under pressure, improper plumbing is more obvious than in the nonpressure sterilizer and is usually corrected. There are several

²² HOLMAN, W. L. and CARROY, A. E. Technical Errors in Studies of Bacterial Variation "Metamorphosis of Streptococci into Spore-bearing Rods," *J. Infect. Dis.*, 56: 165-195, 1935

²³ ECKERT, E. E. and SMITH, R. Sterilizing Surgical Instruments and Utensils, *Med. Hosp.*, 48: 92, March, 1937

²⁴ Chart courtesy Warren Webster Company

²⁵ MÜNDL, O. Über die Bedeutung der Luft für den Wärmegang bei der Dampfsterilisation, *Arch. f. Hyg.* 117: 285-296, February 1937

SANITARY PLUMBING CONNECTIONS FOR STEAM STERILIZER

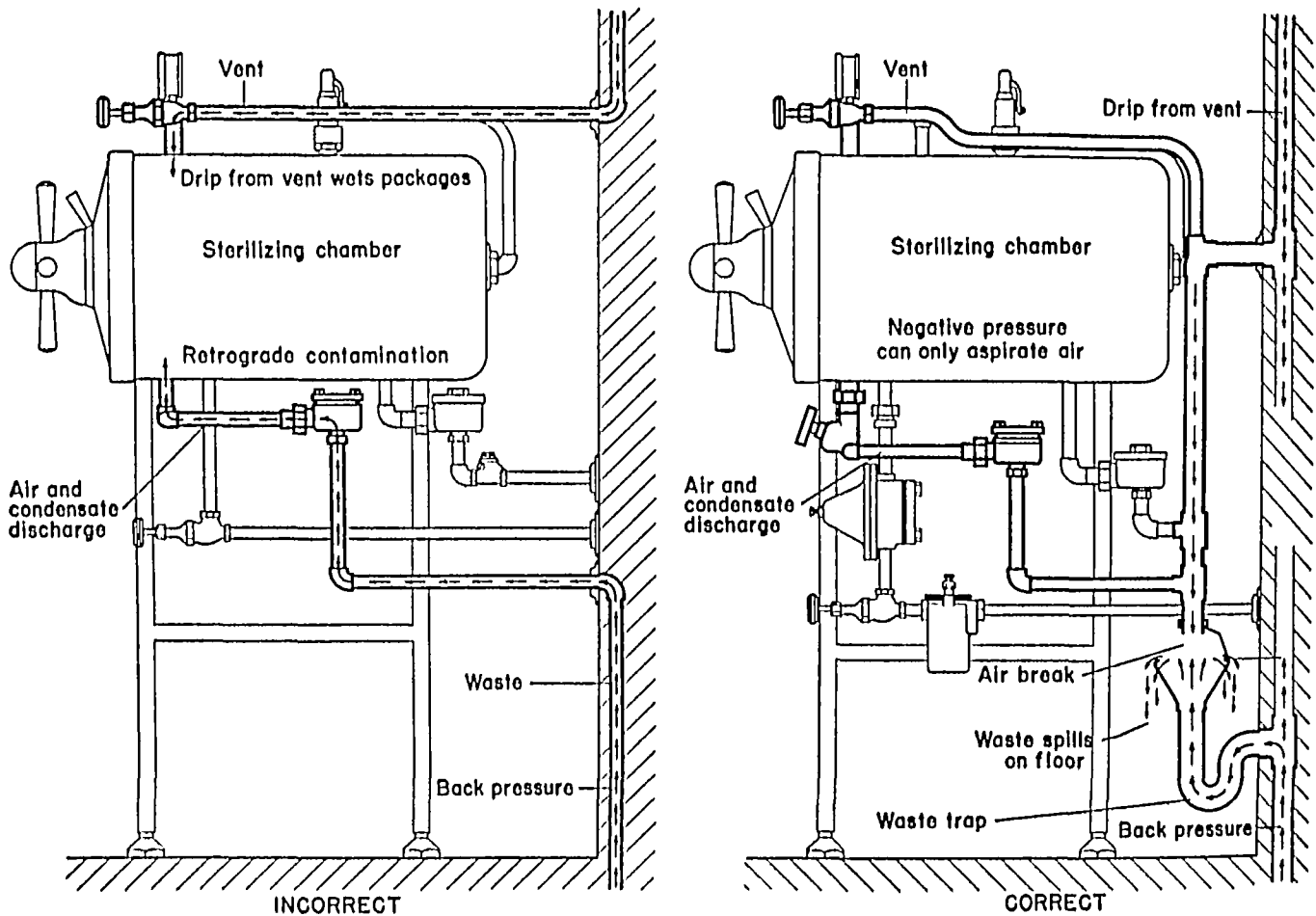


FIGURE 48

DESIGN INFLUENCES STERILIZER EFFICIENCY

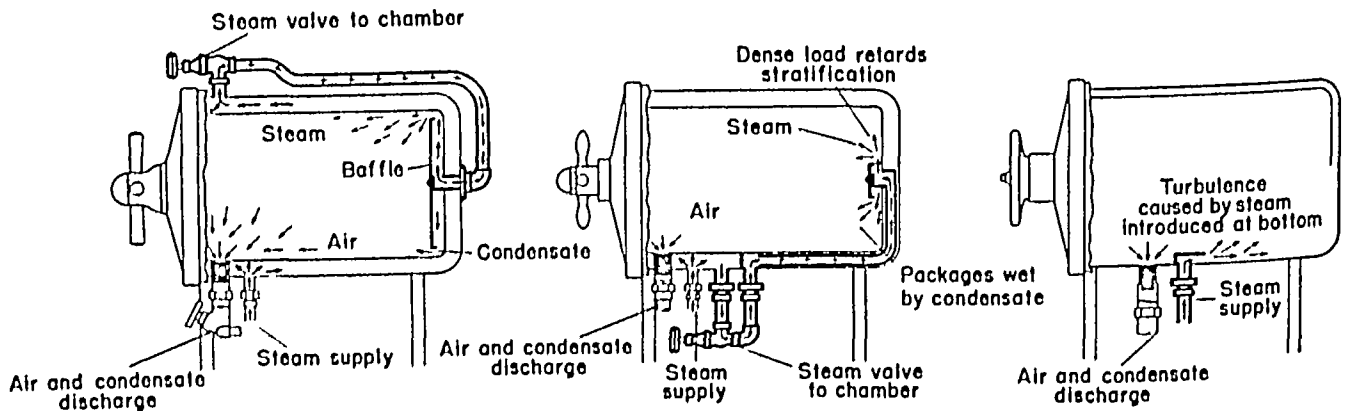


FIGURE 49

POSITIVE CIRCULATION OF STEAM

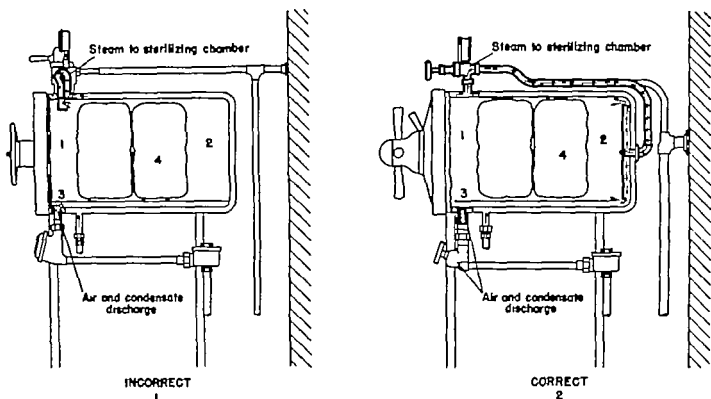


FIGURE 50

points, however, which may easily be overlooked. There should be an air break between the steam sterilizer and the drain because negative pressure frequently develops in a steam sterilizer as it cools, and leaky valves or improper operation can permit the aspiration of the contents of a drainage trap into the sterilizer. Back pressure in the waste line may flood such a sterilizer with waste. Perhaps a more common cause of contamination of sterile loads is improper installation of vent pipes, particularly where more than one sterilizer is serviced by the same vent stack. Condensate from the vent stack has been found dribbling back into the chamber of dressing sterilizers which are cooling. This is one of the causes of wet dressings.

A fifth limitation of steam is inherent in the design of individual types of sterilizers. Several important items should be considered when criticizing the design of a sterilizer. The steam should either be

admitted at the top of the sterilizing chamber or provision must be made whereby steam can readily reach the top of a loaded sterilizing chamber.²² A baffle should be located over the steam port so that the steam does not cause turbulence as it enters the chamber to interfere with the normal stratification of the steam and air. Because the denser air layers are at the bottom, the air discharge must be located at the lowest point in the sterilizing chamber. These points are obvious from inspection of figure 49.

A less obvious fault to be looked for is the failure to provide positive circulation from end to end of a sterilizer. When the steam is admitted at the same end of the sterilizer as the air discharge, overloading may make a cul de sac of the rear of the sterilizer, figure 50, 1. This difficulty can be obviated

²² FROECH, P. and CLAUDENBACH, A. Ueber das Verhalten des Wasserdampfes im Desinfektionsapparate, *Zeitschr. f. Hyg. u. Infektionskr.*, 9:183 1890.

FAULTY DESIGN RETARDS STERILIZATION

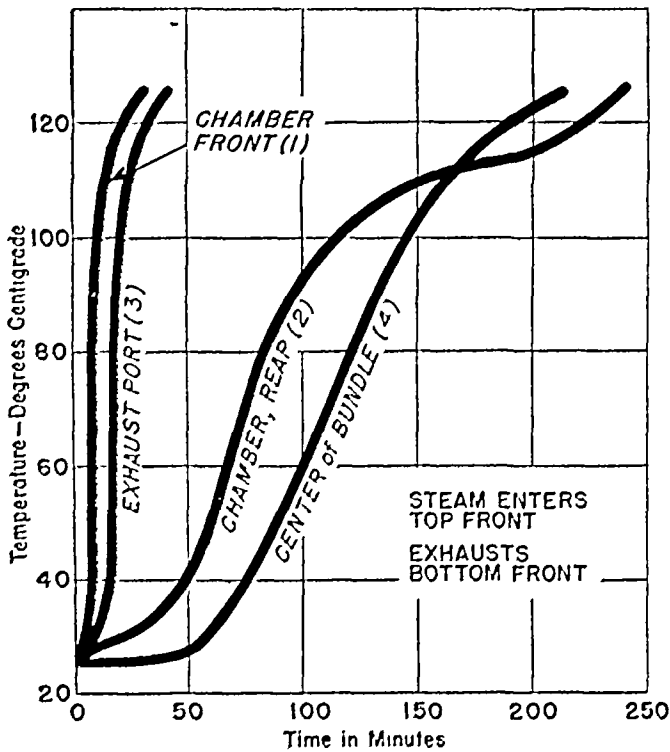


FIGURE 51

simply by locating the steam port and air discharge at opposite ends of the sterilizer, figure 50, 2. The temperature of the bundle in figure 50, 1, has been plotted in figure 51. Contrast this graph with that in figure 52 which depicts the temperature relationships in figure 50, 2, where improved design aids sterilization.

Recall from figure 33 that the quality of saturated steam can readily be ascertained by determining its temperature and pressure. Most sterilizers are fitted with adequate pressure gages but some sterilizers have no thermometer at all or it may be located improperly. To give accurate information regarding the quality of the steam being used as a microbicide, the thermometer should be located in the lowest part of the chamber and should have no valves between it and the chamber.

It has been customary to connect the steam trap draining the jacket of dressing sterilizers with the steam return line, figure 32, so that condensate is returned to the

boiler to conserve the small amount of energy in the condensate. This practice has several disadvantages from the point of view of foolproof sterilization. It puts the sterilizer at the mercy of improperly functioning steam apparatus located elsewhere in the hospital, because a high back pressure in the return line prevents the proper drainage of air or condensate from the jacket. Frequently, condensate from the return line is aspirated into the jacket as the sterilizer cools. Under these conditions the lower walls of the chamber are likely to be cold and wet because the cold condensate or air trapped in the jacket prevents heating. In sterilizers where the steam supply is connected to the bottom of the jacket, this fault is quickly apparent. When the steam is admitted to the jacket in which condensate pools, condensation occurs and the sudden collapse in volume sets up a loud water hammer. As condensate collects during sterilization, a boiling sound is produced by steam bubbling through the hot water. The difficulty can be eliminated readily by arranging the jacket trap so that it dis-

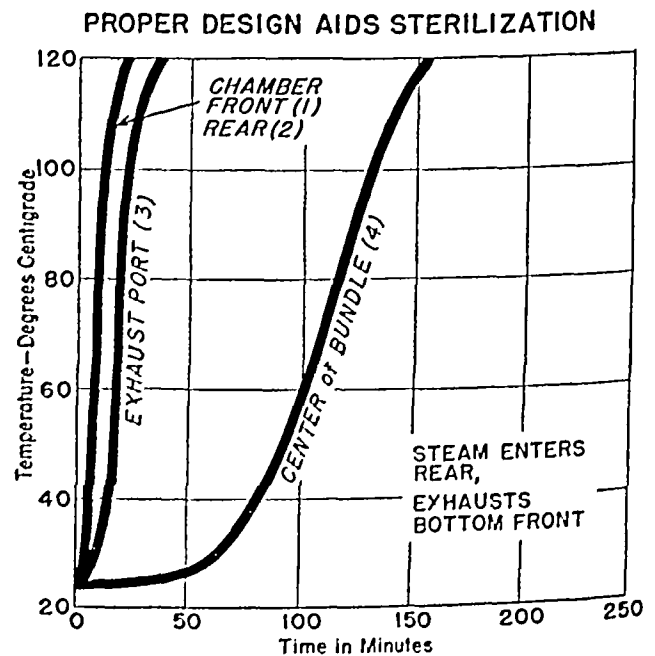


FIGURE 52

PROPER INSTALLATION OF JACKET RETURN TRAP

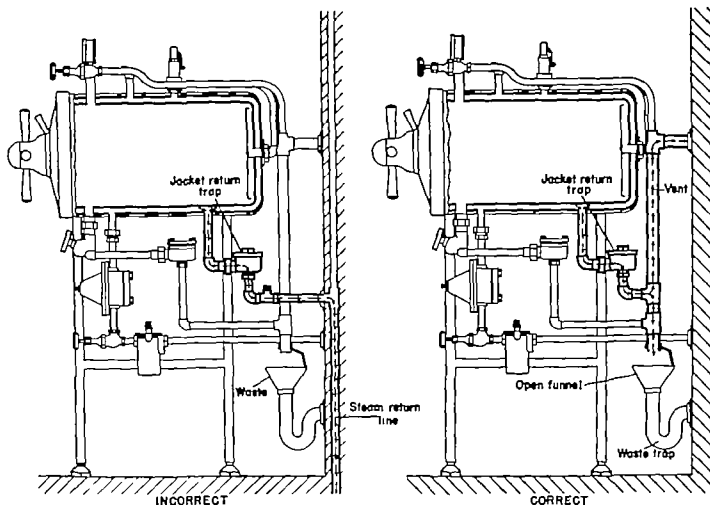


FIGURE 53

charges directly into a waste funnel, figure 53. It may be argued that this is uneconomical but sterilizers are installed to utilize the microbicidal action of steam and, hence, sterilization must be considered an end use for steam. The conservation of the small amount of condensate is unjustifiable if it interferes with the purpose of the sterilizer.

Fortunately the limitations of saturated steam as a sterilizing agent can be overcome readily. The removal of air is the only point that requires detailed discussion. Air is a constant hazard wherever steam sterilizers are used because human factors determine whether the mechanical provisions for air clearance are successful. Air can be removed by pumping it out. This method

is improperly utilized by those who draw a partial vacuum as the initial step in sterilization. This custom is useless because only one third of the air is removed and the residual two thirds are sufficient to interfere with sterilization, figures 44 and 45. The cost of pumping out most of the air is unjustified because the physical properties of air-steam mixtures afford a more direct approach to the problem.

The fact that air is twice as heavy as steam and does not mix readily with it is the key to reliable air clearance.^{26 27 28} The heavy air gravitates to the bottom whence it escapes through any orifice just as water

²⁶ GRUBER, M. Erklärung der Desinfektionskraft des Wasserdampfes, *Zentralbl. f. Bakt.*, 31634-638 1888.

EFFECT OF AIR ON CHAMBER TEMPERATURE

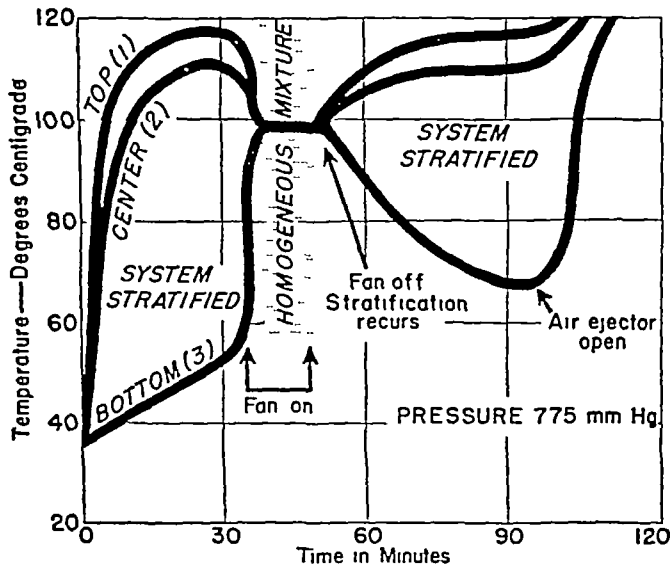


FIGURE 54

Walter³⁵

runs out of a bath tub when the drain plug is removed. A useful analogy is that shown in figure 55, 1. An ordinary fish aquarium fitted with an air ejector portrays accurately what occurs as steam is admitted to a sterilizer. The water, representing the air which initially fills the sterilizer, is heavier than the steam, represented by the air overlying the water in the aquarium, and stratification occurs. As steam rushes in, it layers over the cold heavy air, forcing it downward and outward through the air ejector, figure 55, 2. The analogy is useful for analyzing many problems which arise in sterilizing practice. Any container in which water pools in the aquarium will also trap air in a sterilizer, so the analogy can be carried one step farther as shown in figure 55, 3, 4, where the only vessel which clears air promptly is the horizontal beaker. In the upright beaker, it is obvious that air is trapped, in the inverted beaker, air clearance is delayed until steam creeps around the edge, as in the familiar poultry drinking fountain, to replace the air. Just as obviously, but often overlooked, air is trapped in hermetically sealed containers. The tightly corked bottle, the

tightly capped jar, effectively protects its contents against sterilization. If dry bottles are to be sterilized, they must be positioned as shown in the analogy to assure air clearance, in figure 55, 3.

The detrimental effect of air on steam sterilization is illustrated in terms of actual temperatures attained in an autoclave (unjacketed type containing one cubic meter) into which saturated steam was admitted under 750 mm Hg gage pressure. The air which initially filled the chamber was retained by closing the air exhaust line. Thermocouples (1, 2, 3), located as shown in figure 47, measured the temperature of the air and steam system at the respective levels indicated. The lighter, hotter steam (45 cu m; density 1.17 kg per cu m; temperature 115°C) layered over the heavier, colder air (55 cu m, density 2.17 kg. per cu m, temperature 54°C) which was compressed into the lower half of the chamber, figure 54.³⁵

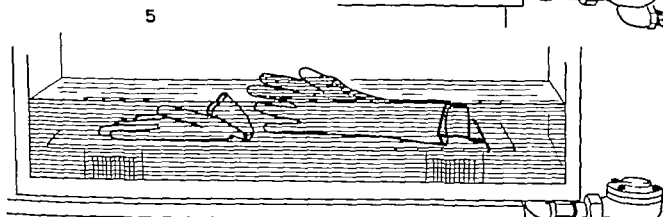
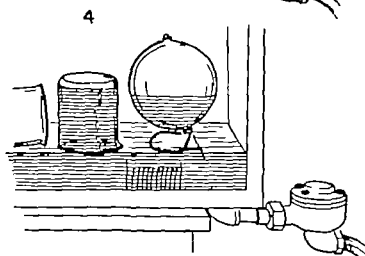
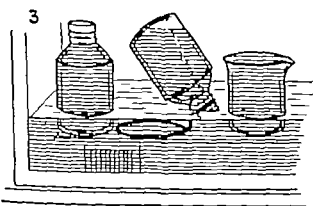
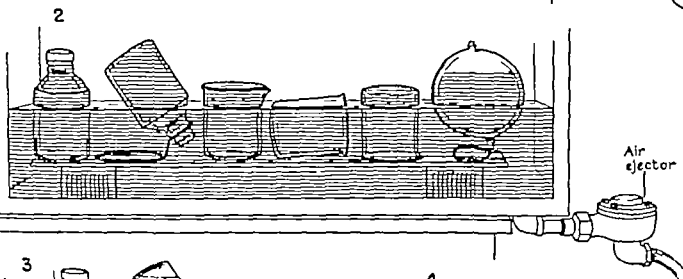
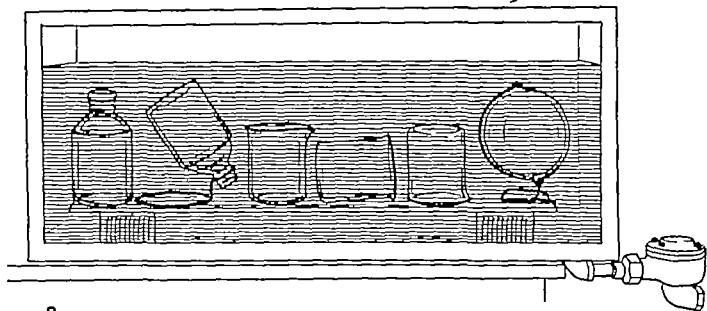
Such a stratified system maintains itself indefinitely unless convection currents are established.³⁶ In this experiment an electric fan was used to create a homogeneous mixture at 107°C. The fact that stratification recurred as soon as the fan was stopped is of great importance for sterilization because it illustrates that air and steam do not form a stable mixture. This explains why air can be removed from a sterilizer, yet, paradoxically, it remains trapped in an uncovered, upright container in the otherwise air-free chamber.

When the exhaust line was opened, the air was displaced by forcing steam into the sterilizer under pressure. The completeness of the air ejection is shown by the tempera-

³⁵ WALTER, C. W. Aseptic Technic—The Sterilization of Dressings and Dry Goods, *Internat Abstr Surg*, 71:414, 1940. By permission of *Surgery, Gynecology & Obstetrics*.

³⁶ KONRICH, HEUSE, GINS and KUNERT. Über Dampfsterilisation mit Luftabscheider, *Ztschr f Hyg u Infektionskr*, 117:1-6, 1935.

WATER ANALOGY OF STEAM STERILIZATION



DRESSING CAN AND DRUM

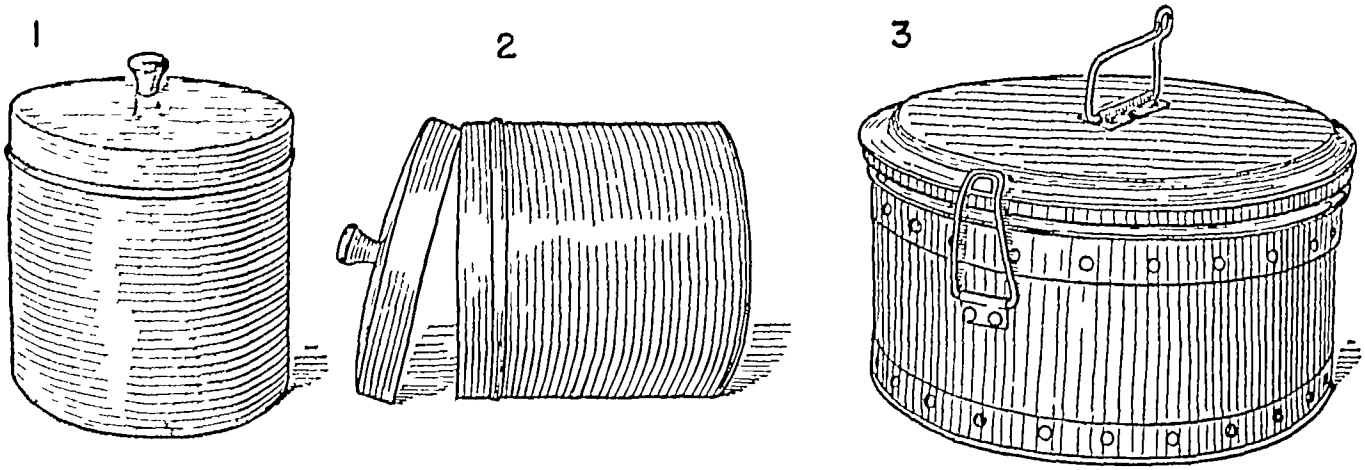


FIGURE 56

ture at the bottom of the chamber which rose to 121°C and indicated that saturated steam under a pressure of 750 mm. Hg gage pressure filled the entire chamber. The importance of providing a horizontal path for air escaping downward and the reliability and effectiveness of gravity air clearance are well illustrated by this graph.

Two factors influence air clearance. There must be a horizontal path for the escape of air from impervious containers. The hospital dressing can illustrated in figure 56, 1, is analogous to the beaker when put in the sterilizer in the upright position — it pools air. To insure rapid sterilization, it must be placed on its side in the sterilizer with its lid off, figure 56, 2.

The second factor is that the path for the escape of air must be sufficiently large to permit rapid interchange of air and steam. At the right in figure 55 is an analogy of a hospital dressing drum. Two petri dishes, fused together about the periphery, represent a dressing drum. The area of the holes at the top and bottom bear the same relation to the volume of the petri dishes as the holes about the periphery of a dressing drum, figure 56, 3, bear to its volume. The delayed air clearance is obvious in the aquarium. Figure 57 illustrates

that steam must have free access to packages to insure rapid, dependable sterilization. Metal containers limit the surface of the package exposed for the interchange of air and steam and may retard sterilization. This is illustrated by the heating curves of rolls of sheeting 12 cm thick by 45 cm. in diameter. One was wrapped in four thicknesses of muslin; the other was enclosed in the conventional dressing drum. Both were placed in the sterilizer on edge. The perforations about the periphery of the drum were open. The chamber temperature rose to sterilizing level in twenty minutes. The muslin-wrapped roll was penetrated in sixty-five minutes, while the roll in the dressing drum was not heated throughout for one hundred seventy-five minutes. The limitation of area available for the interchange of air and steam to the perforations about the periphery of the drum was responsible for the delayed penetration. Metal dressing drums are expensive, noisy, and cumbersome. They contribute little to aseptic technic and should not be used.^{37, 38}

A test for air clearance is essential for the safe operation of a steam sterilizer. For-

³⁷ MIESNER, H., SCHOOP, G. and HARMS, F. Verbandstoffsterilisation im Autoklaven, *Zentralbl f Chir*, 64,498, 1937

tunately, such a test is applied readily. Figure 33 defines the physical properties of saturated steam and makes its identification easy. A pressure gage attached to the sterilizing chamber gives a pressure reading. A thermometer located in the lowest point of the chamber yields a reliable temperature reading because, as shown in figure 54, any free air in the sterilizer always gravitates to the bottom. Unfortunately, the measurement of temperature is not applicable unless the articles to be sterilized have been suitably packaged and the sterilizer properly loaded because from the water analogy,

■ KUMERT H. Verkürzung der Betriebszeit bei der Dampfsterilisation mit Luftabscheider. *Ztschr f Hyg u. Infektionskr* 116:295 1934

figure 55, it is obvious that free air can spill out of the sterilizer but air may be trapped in impervious containers or faultily wrapped packages.

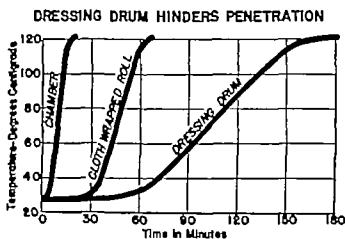


FIGURE 57

Waller²⁵

CHAPTER VIII

THE CONTROL OF STEAM STERILIZATION

Every surgical operation is an experiment in bacteriology

—ARTHUR TRACY CABOT¹

The routine control of steam sterilization requires the integration of nine factors which influence the efficacy of the process.

1 The period necessary to heat the largest package throughout must be known. This can be controlled by establishing a standard size, shape, and internal arrangement for the largest bundle of dry goods as described in Chapter X. When sterilization is strictly a surface phenomenon, as in the sterilization of instruments, other factors influence the length of exposure, as detailed in Chapter XI. The period required to heat flasks of solution to sterilizing temperature is discussed in Chapter XVIII.

2 The sterilizer must be loaded to provide a horizontal path for the escape of air.

3 The quality of the steam used in the sterilizer must be determined. The temperature of the fluid in the exhaust line indicates whether air, steam, or a mixture of the two occupies the lower portion of the sterilizer. If the chamber pressure is 775 mm Hg gage, the temperature in the exhaust line will rise to 121°C when saturated steam has displaced the air and fills the chamber.²

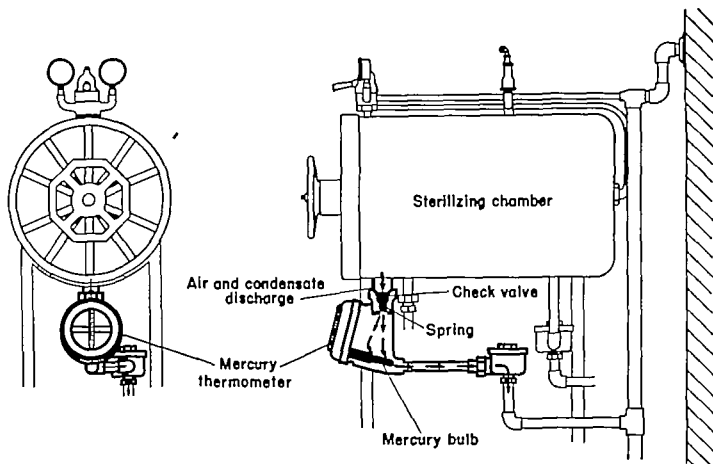
¹ Quoted by Walker, I J, in *Surg, Gyn & Ob*, 60 275, 1935. By permission *Surgery, Gynecology & Obstetrics*.

² WALTER, C W. The Sterilization of Dressings and Dry Goods, *Internat Abstr Surg*, 71 414-419, 1940. By permission of *Surgery, Gynecology & Obstetrics*.

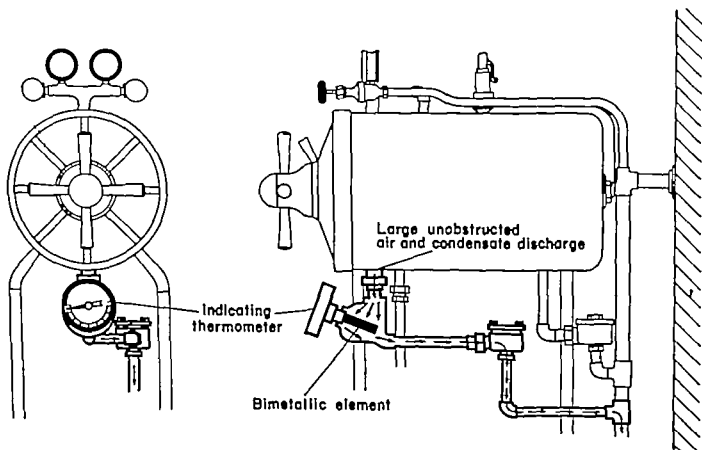
The temperature is best measured by an indicating thermometer either of the mercury or bimetallic type installed in the air exhaust line. If the exhaust line is properly designed, the thermometer indicates the temperature of the fluid in the chamber promptly and accurately. Figure 58 illustrates two types of thermometers commonly in use. The type shown in figure 58, 1, is usually installed with instructions to begin the sterilizing cycle when the thermometer reaches the 115.5°C level. This apparent discrepancy is due to the design of the air exhaust line which precludes the immediate development of 1536 mm Hg pressure about the bulb of the thermometer and so the indicated temperature lags that in the chamber. Sterilization is actually done by steam at 121°C, hence, the thermometer reading is deceptive. The type illustrated in figure 58, 2, indicates the actual temperature of the fluid being used for sterilization quickly and is read easily.

4 The period of continuous exposure to saturated steam must be measured. The installation of a reliable clock in the sterilizing room is so obviously important for the accurate control of sterilization that it is usually forgotten. The use of individual wrist or pocket watches is dangerous because too frequently a sterilizer is started by

THERMOMETRIC CONTROL OF STERILIZATION



1



2

TIME-TEMPERATURE RELATIONSHIPS IN STERILIZING CYCLE

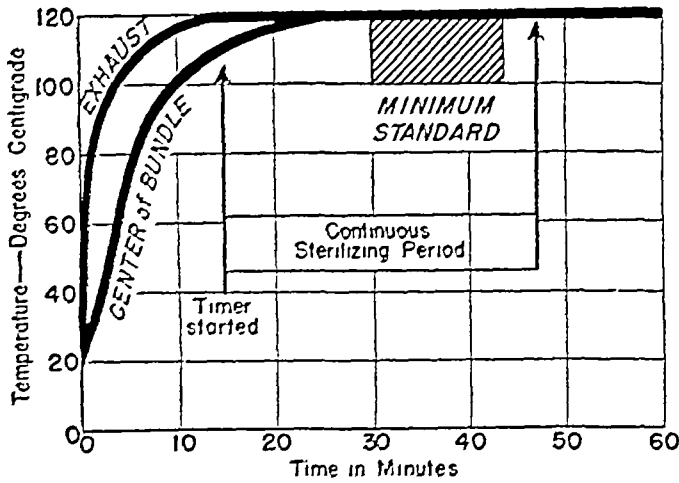


FIGURE 59

Walter²

one attendant who times it by his watch and is turned off by another at the time indicated by a second watch. If the watches agree, the load is sterile; if the first one happens to be slow or the second one fast, the sterilizing period is inadequate.

Continuous exposure is essential because as steam penetrates a package, it condenses in the package in quantities proportional to the heat required to raise the temperature of the material to that of the steam. The heating spreads centripetally in a distinct zone of demarcation, the temperature necessary for sterilization exists only where the goods are moist; a few centimeters in advance of the zone, the fabric is dry and relatively cool. If this orderly heating is checked, the outer wet shell of moist fabric cools and must be reheated. This may require a longer exposure than the original dry package. For example, if the outer one third of the package cools to 100°C, 30% more steam is required to reheat the outer wet shell (two thirds of the package by weight) because the condensate left in the fabric by the initial heating requires additional heat.

In the large sterilizer used in the experiment in which the data for figure 59 were collected, the thermocouple located in the

exhaust line indicated the presence of saturated steam at 121°C in seventeen minutes. The air had therefore been ejected. The thermocouple in the center of the bundle did not indicate complete penetration by steam until thirteen minutes later. Peak microbicidal action begins in the center at this point and must be continued until all bacterial life is destroyed. It is not practicable to measure the temperature of the center of bundles routinely. A more convenient method of measuring the sterilizing period is to note when saturated steam fills the chamber as indicated by the temperature of the exhaust line. A period of thirty consecutive minutes provides for (1) complete penetration of a load of standard packages plus (2) thirteen minutes requisite for destruction of the least accessible spore by saturated steam at 121°C, as is indicated in figure 37.

5 Reliable personnel must be provided. Simply determining the physical facts indicative of a properly functioning steam sterilizer is not enough. The uncertainties of human behavior are so great and human error is so likely to negate sterilization in the best sterilizer, that other safeguards must be used. It is imperative that permanent personnel be employed who are properly trained in packaging and loading and who realize their responsibility and perform their duties wholeheartedly. The sterilization of hospital supplies is a service essential to the safety of the patient and not a chore to be relegated to the most stupid or least expensive employee. Certainly, it is not a task to be entrusted to volunteers.

6 There must be a logical correlation between the quantity of work to be done and the personnel and equipment provided to do it. Even efficient personnel cannot be expected to do a good job with inadequate facilities. The necessity of overloading sterilizers must be eliminated by the provision

SAFETY LOCKS TO PROTECT OPERATOR

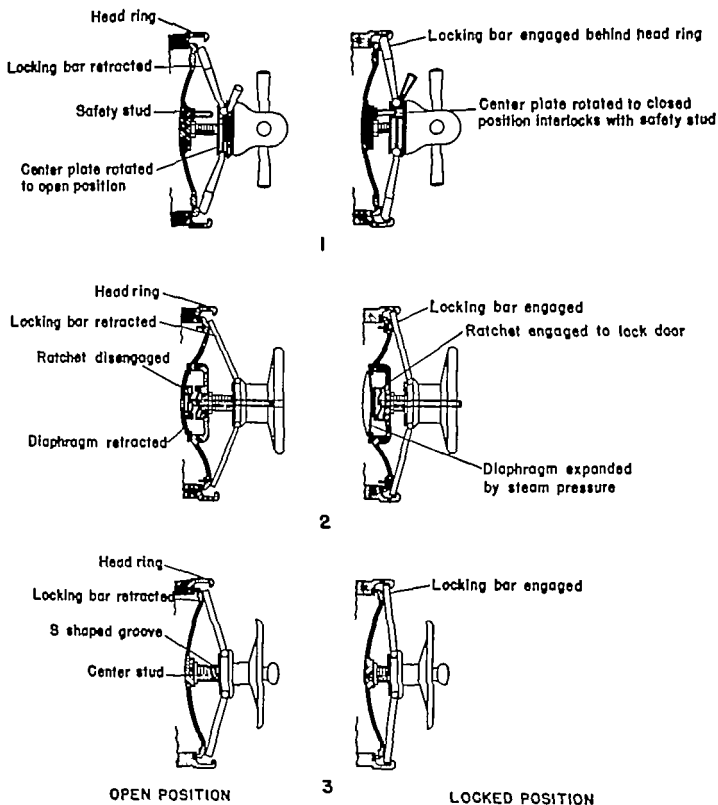


FIGURE 60

AUTOMATIC TIME-TEMPERATURE CONTROL OF STERILIZATION

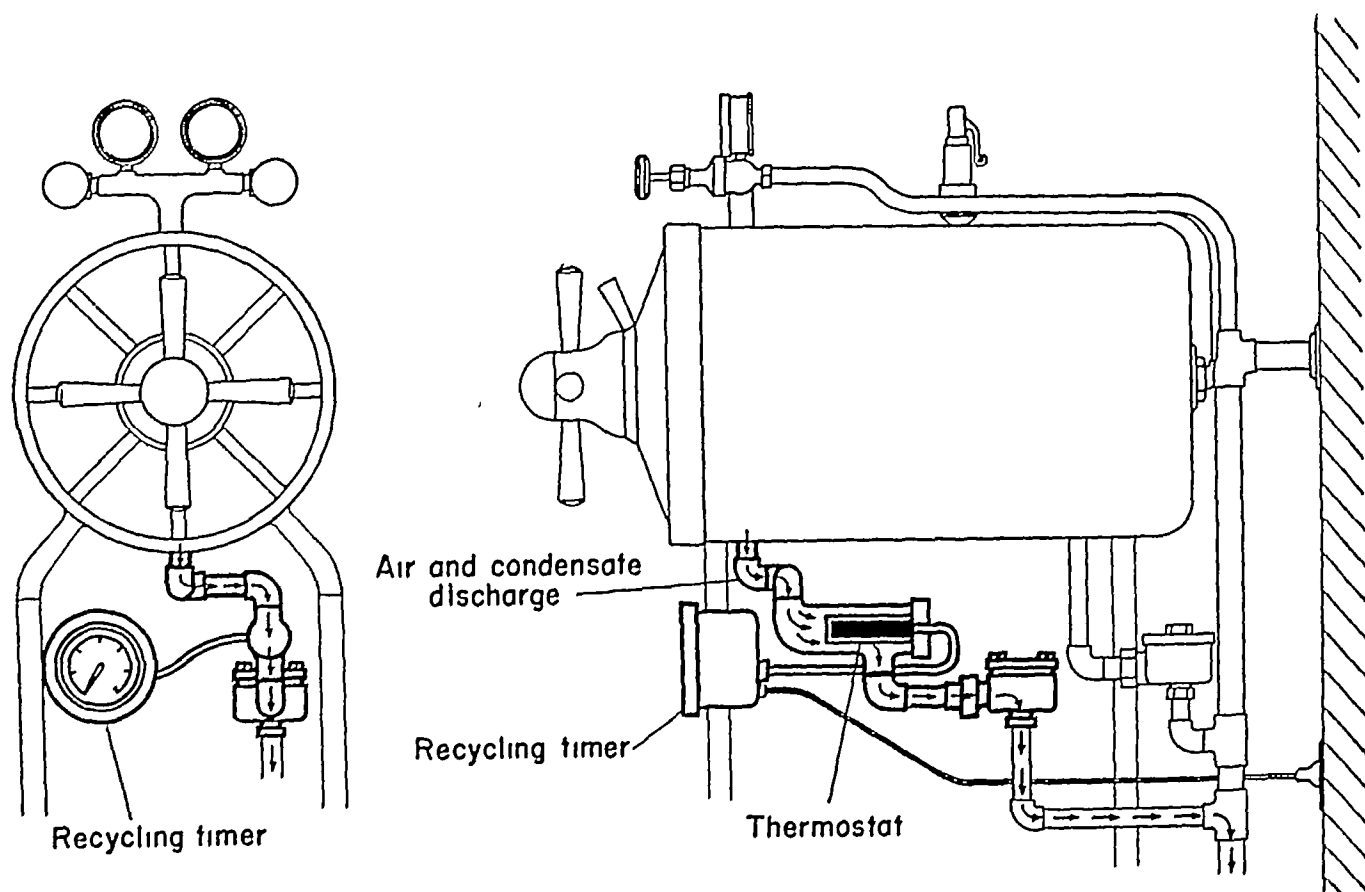


FIGURE 61

of adequate sterilizer capacity (cubic meters of usable space, not the number of sterilizers) to permit operation at no more than 85% of capacity during the normal working hours of the sterilizer attendants. Inadequate sterilizer capacity is one of the most frequent faults found in modern hospitals.

7. The sterilizer must be in good condition. An unappreciated factor in failure of sterilization is faulty maintenance of equipment. Sterilizing equipment should be inspected periodically by a trained mechanic who understands the design and use of sterilizers and appreciates the importance of their proper maintenance. Discretion must be used in the interpretation of the mechanic's reports on the condition of sterilizers. Many intelligent sterilizer at-

tendants are forced to use defective equipment because of the opinionated ignorance of those charged with the maintenance of sterilizers and their source of steam. For example, 500 telltale indicators were gathered during a three-day inspection tour of the operating rooms of a large teaching hospital. None indicated exposure to steam. When questioned, the supervisor produced a letter from the superintendent of the hospital ordering her to disregard the indicators because the mechanic had reported the sterilizer in good shape and that the fault lay with the indicators. The thermometer on that sterilizer was broken and the air ejector was plugged. The maintenance of sterilizers is discussed at length in Chapter XXI.

RECORDING THERMOMETER

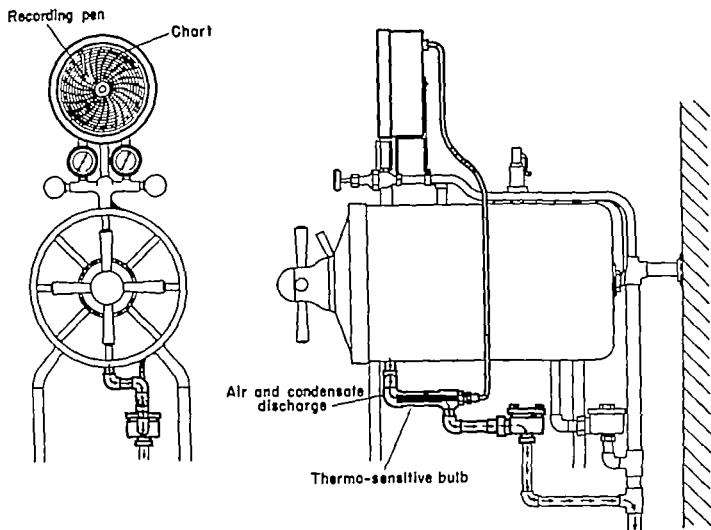


FIGURE 62

8 Legible, clearly illustrated instructions for the proper operation of the specific sterilizer should be framed and mounted near by where they may serve to standardize operation.

9 Continuous check on the sterilizing process must be made. Because personnel problems necessarily influence the control of sterilization, various attempts have been made to provide mechanical controls to safeguard the process. Some of these are merely safety devices to protect the operator against injury. Figure 60 illustrates safety equipment designed to prevent a careless operator from opening a sterilizer door while there is pressure in the chamber. One, figure 60, 1,

relies upon mechanical interlocking of the center plate, which controls the locking bars of the sterilizer door, over a safety stud so that the steam pressure is necessarily released gradually as the door is unlocked, it being impossible to retract the locking bars until the steam has escaped. Thus, the door cannot fly open suddenly and injure the operator. Another, figure 60, 2, provides a mechanical lock actuated by steam pressure on a diaphragm to prevent the door being opened until the steam pressure has been relieved and the diaphragm has disengaged the lock. Another type, figure 60, 3 has a groove in the center stud which guides the center plate and

CHART SHOWING FAULTY STERILIZATION

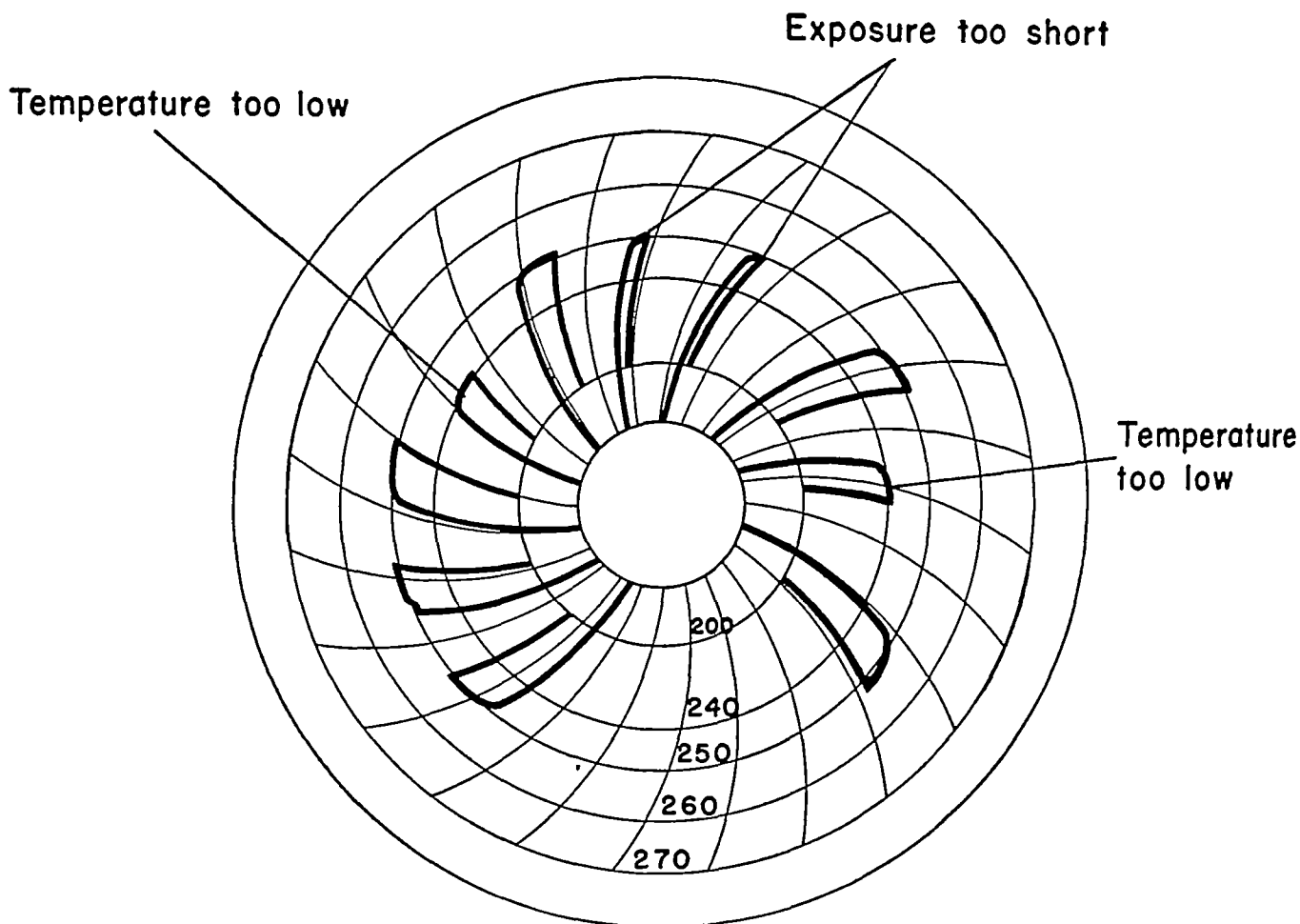


FIGURE 63

automatically retracts the locking bars only after the door is free from the gasket so that all steam has escaped about the periphery. This type of safety protects the careless attendant. Safety for the patient demands devices to force the personnel to operate sterilizers so as to assure sterile supplies.

An automatic time-temperature ratio can be insured by the installation of the device illustrated in figure 61. It consists of a sensitive thermoresponsive switch located in the air exhaust line. When saturated steam at 121°C contacts the switch, the clock is started. Whenever the switch cools, the clock stops and recycles to 0. Thus, the elapsed time indi-

cated on the dial means that the thermostat was exposed continuously to saturated steam above 121°C for that period. In the ultimate analysis, the control of sterilization depends upon the coordination of machine and personnel for reliable results. The ideal technic standardizes packaging and loading so that only one period of sterilization is necessary, hence, the machine can be equipped with a nonadjustable timer which will enforce the minimum standards necessary to sterilize the standard package. Another device of this type is the recording thermometer, having a thermoresponsive bulb inserted into the air exhaust line, figure 62. The recorder indicates the time-

ADJUSTABLE TIMER

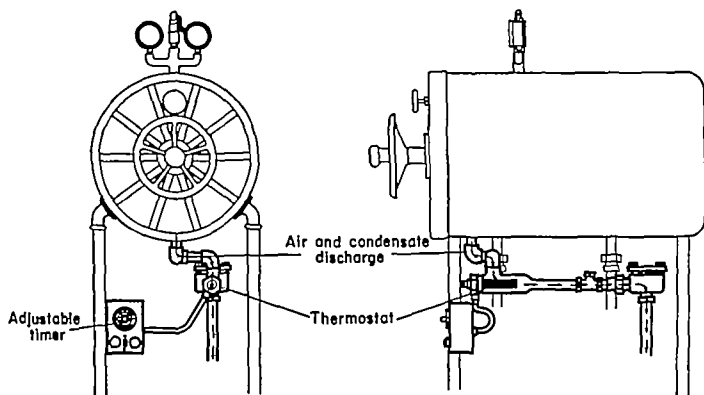


FIGURE 64

temperature relationship on the chart. The difficulty with both these devices is that there is no assurance that the sterilizer attendant will operate the sterilizer as dictated by the control device. The problem is illustrated in figure 63, showing a recording thermometer chart which was presented to a hospital superintendent as a daily routine. He found that three loads were inadequately sterilized but no one knew whether or not those loads had been re-sterilized or distributed throughout the hospital as sterile. Recording devices in current use should be checked because, at one time, recording pressure gages were installed which indicated pressure but were calibrated in terms of temperature. The pressure, of course, might be due to water or air as well as steam.

Some sterilizers are equipped with timing devices and thermostats which are adjust-

able, figure 64. Because of the adjustable feature, none of this type are safety controls because lazy or dishonest employees can readily adjust either time or temperature to suit their own convenience.

Another control goes still further because it forces the personnel to correlate interpretation of the indicators of sterility with the actual operation of the sterilizer and the safe disposition of the load. The control illustrated in figure 65 automatically impounds the load until it has been properly sterilized, thus eliminating opportunity for human error.² The autoclave door is locked by a rolling key clutch mechanism mounted within the hand wheel assembly, figure 65, 7. This clutch wedges the hand wheel so that the locking bars cannot be retracted and

²WALTER, C. W. A Reliable Control for Steam Sterilization, *Surg. Gyn. & Obs.*, 67:526-530 Oct., 1938. By permission of *Surgery Gynecology & Obstetrics*.

TIME - TEMPERATURE CONTROL FOR STERILIZATION

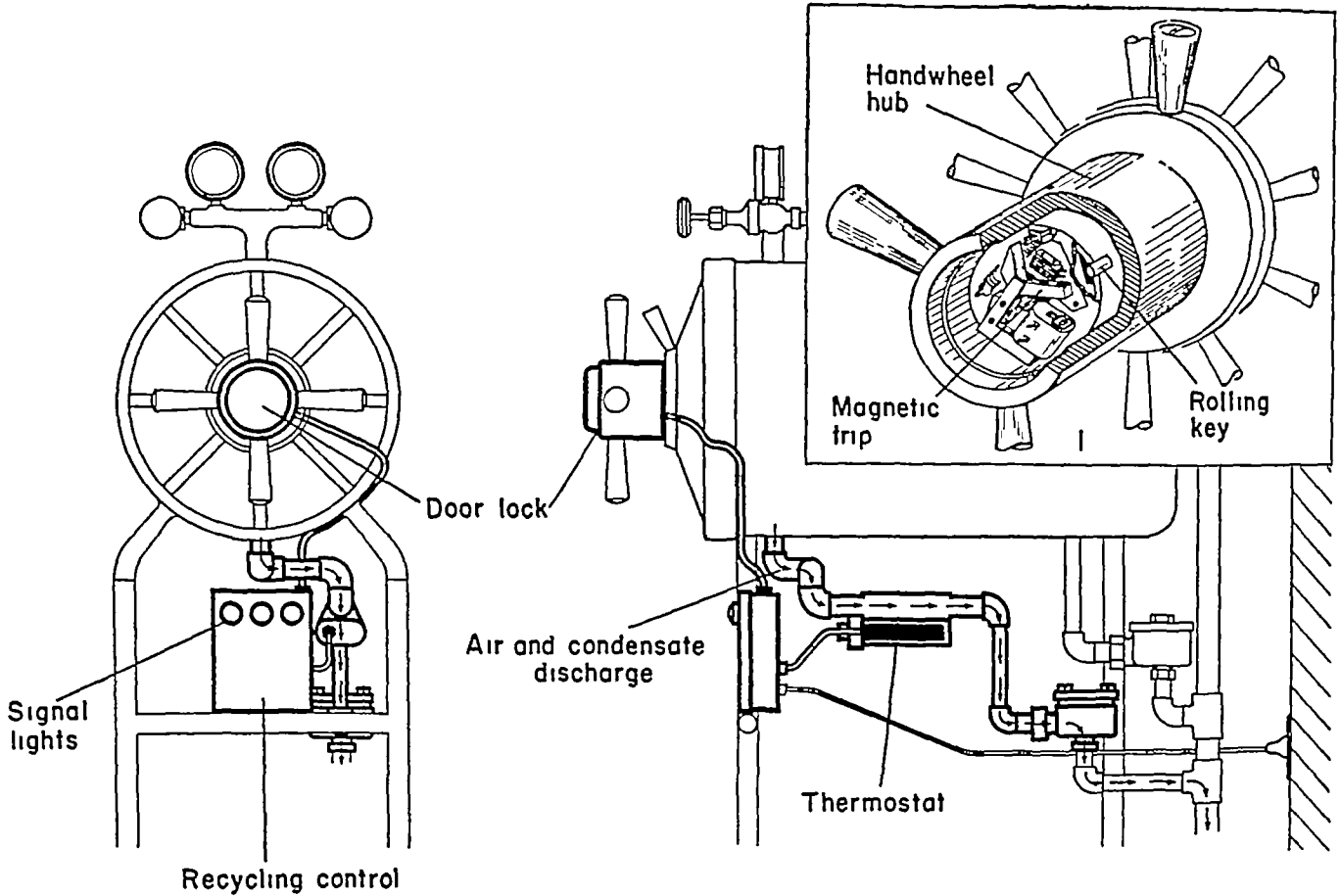


FIGURE 65

simultaneously provides the take-up often necessary for sealing the door against leakage of steam as the chamber pressure builds up. After the satisfactory completion of the sterilizing cycle, the rolling keys are released from their wedging position by a magnetic trip.

The sterilizing cycle is checked by a recycling, synchronous electric timer which is controlled by sensitive thermostats located in the exhaust line of the sterilizer.

The sterilizer is operated according to the manufacturer's usual instructions. When the locking bars are forced into position to secure the sterilizer door, a switch is actuated which energizes the control. After steam has been admitted to the chamber and the temperature of the steam reaches the sterilizing level, a thermostat, set for 121°C , starts the timer, figure 65. A signal

indicates that sterilizing conditions prevail. While the temperature of the steam remains above 121°C , the timer meters a consecutive interval until thirty minutes have elapsed, when it trips a switch which lights a signal, indicating that the load is sterile and that the steam may be shut off and the vent valve opened. After the pressure in the chamber has been relieved and the temperature falls to 100°C , a second thermostat closes, releasing the clutch so that the hand wheel may be turned to retract the locking bars.

If for any reason the temperature of the steam falls below 121°C , the timer automatically recycles and the entire thirty-minute period must be repeated. Thus, continuous exposure to saturated steam destructive to bacterial life is assured.

This automatic control provides the sur-

A RELIABLE CONTROL FOR STEAM STERILIZATION

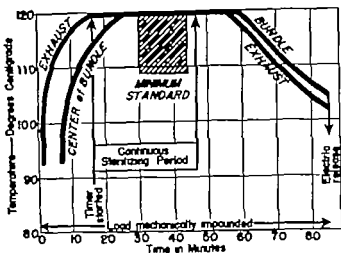


FIGURE 66

Walter³

TEST APPARATUS FOR TELLTALE CONTROLS

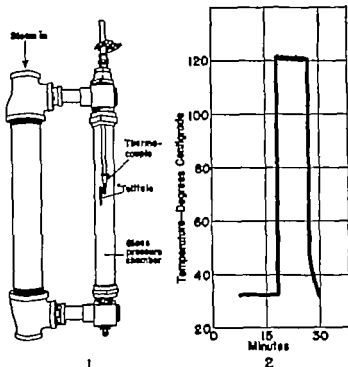


FIGURE 67

Walter⁴

geon with a reliable method of eliminating faulty sterilization due to failure of the sterilizing equipment and ignorance or negligence on the part of the attendant. It enforces adherence to a predetermined standard of sterilization, figure 66, sufficient to insure absolute sterility of surgical supplies without waste of steam or damage to fabrics because of excessive exposure to steam.

A group of controls known as "telltale" has been devised to show whether a given package has been sterilized. This group was carefully studied in a glass autoclave, figure 67, 1, where they could be observed while surrounded with saturated steam.⁴ An adequate steam supply and vent permitted prompt air ejection and rapid rise and fall in temperature, figure 67, 1. A recording potentiometer provided a graphic record, figure 62, 2, of the temperature measured by a thermocouple from which the telltale was suspended.⁴

The lag thermometer, figure 68, demonstrates faults typical of the group. The location of the telltale in the sterilizer influences

the significance of the information it provides. In figures 47 and 54, it is obvious that an indicator at the top of the bundle would indicate sterility whereas the bottom remains unsterile. The location of the telltale is a haphazard procedure which can be controlled only by rigid discipline of attendants, which in itself solves most of the problems in controlling sterilization. The lag thermometer is intended to be wrapped in the center of packages and withdrawn by means of a tape so that it can be read while still hot. If packages are wrapped so that these indicators can be withdrawn readily, the performance of the indicator need not simulate that of the package in which it is enclosed because the channel provided for easy withdrawal invites early penetration by steam, and hence, the indicator may be heated before the material surrounding it. It is so large that the channel through which it is removed invites contamination of the pack during storage.

Other factors militate against the lag

⁴WALTER, C. W. An Evaluation of Sterility Indicators, *Surgery* 2:585-589 1937

TIME-TEMPERATURE CONTROL FOR STERILIZATION

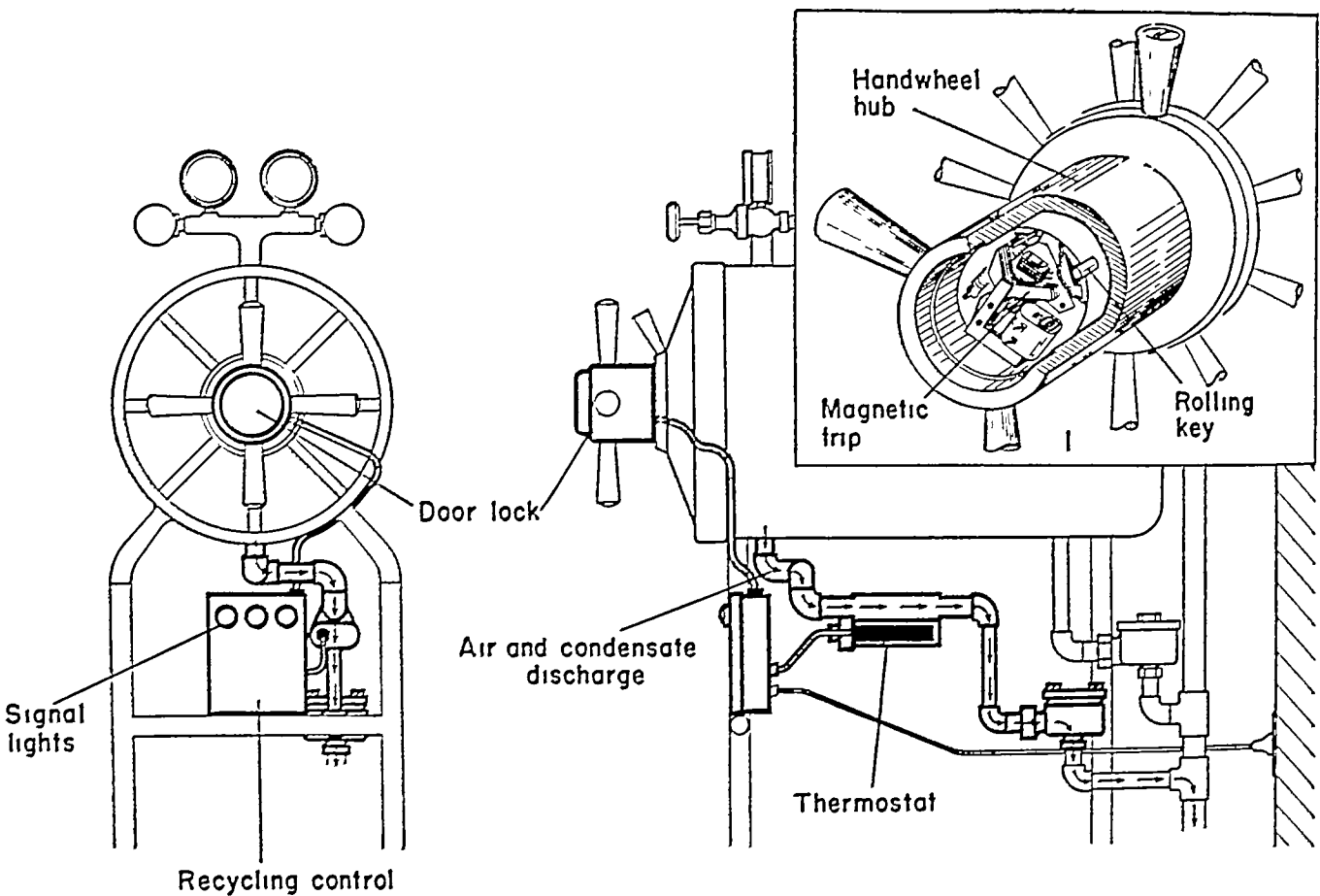


FIGURE 65

simultaneously provides the take-up often necessary for sealing the door against leakage of steam as the chamber pressure builds up. After the satisfactory completion of the sterilizing cycle, the rolling keys are released from their wedging position by a magnetic trip.

The sterilizing cycle is checked by a recycling, synchronous electric timer which is controlled by sensitive thermostats located in the exhaust line of the sterilizer.

The sterilizer is operated according to the manufacturer's usual instructions. When the locking bars are forced into position to secure the sterilizer door, a switch is actuated which energizes the control. After steam has been admitted to the chamber and the temperature of the steam reaches the sterilizing level, a thermostat, set for 121°C , starts the timer, figure 65. A signal

indicates that sterilizing conditions prevail. While the temperature of the steam remains above 121°C , the timer meters a consecutive interval until thirty minutes have elapsed, when it trips a switch which lights a signal, indicating that the load is sterile and that the steam may be shut off and the vent valve opened. After the pressure in the chamber has been relieved and the temperature falls to 100°C , a second thermostat closes, releasing the clutch so that the hand wheel may be turned to retract the locking bars.

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A RELIABLE CONTROL FOR STEAM STERILIZATION

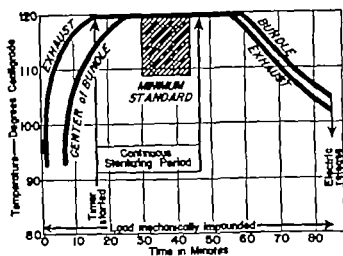


FIGURE 66

Waller³

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TEST APPARATUS FOR TELLTALE CONTROLS

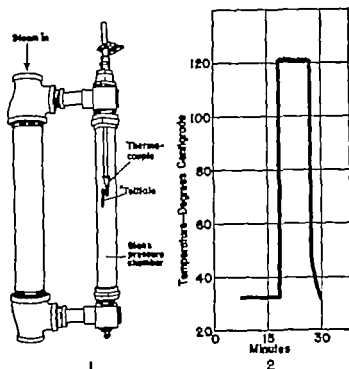


FIGURE 67

Waller⁴

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Other factors militate against the lag

⁴WALLER, C. W. An Evaluation of Sterility Indicators, *Surgery* 21:585-589 1937

LAG THERMOMETER

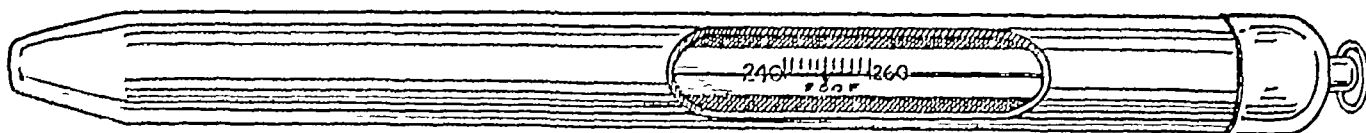


FIGURE 68

thermometer. The attendant must be relied upon to allow the thermometer to cool for thirty minutes and to shake it down before it is re-used. Study in the glass autoclave shows that the thermometer registers 121°C in five to seven minutes instead of fifteen minutes as advertised. The mercury column can be set at any point on the scale at will. The thermometers are fragile and expensive and add more hazards to sterilization than they remove.

Another variety of sterility indicator is the small expendable glass tube or paper tab intended to be wrapped in the center of packages either to be withdrawn at the end of sterilization or to be inspected when the package is ultimately used.

A study of the melting point of the pink head type of control (Diack) not only revealed marked discrepancies between individual controls but also with earlier published and advertised claims.^{5, 6} The end-point of this control (a change in shape) was clear but it developed equally well in dry or moist heat. The majority of the 1000 beads tested melted in one minute or less when exposed to saturated steam at customary sterilizing temperatures, figure 69. A number showed a melting point delayed sufficiently to cause undue waste in sterilization, if sterilization was repeated

under the erroneous assumption that the unmelted bead indicated failure of sterilization.

"Armour Tubes" and "Telotest" are examples of telltales which react equally well to dry and moist heat and hence are valueless in steam sterilization.

Observations on the matching of the color of the bulb or printed replica of a thermometer (Sterilometer), which changes color after brief contact with steam with the delayed production of color in the column, were difficult because of the exceedingly poor end-point. Even the latest type of this control showed a gradual development of color which began early and progressed to a point where further darkening, due to the formation of lead sulphide, could not be

MELTING POINT OF RED BEAD
IN SATURATED STEAM

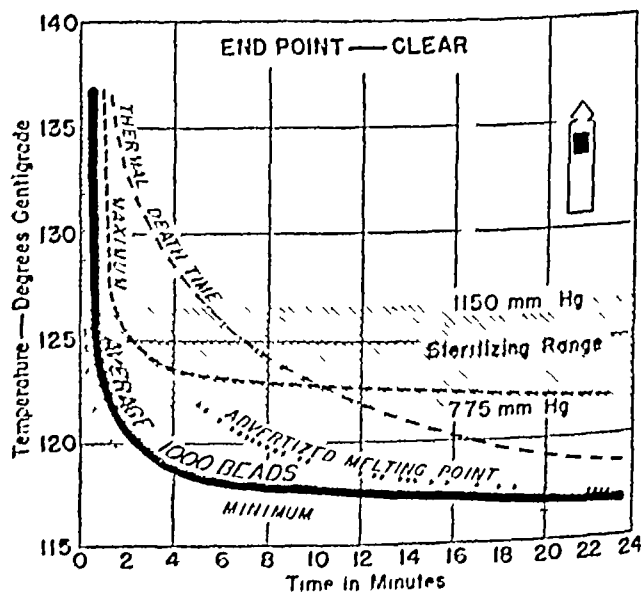


FIGURE 69

Walter⁴

⁵Horr, A. Studies on Rubber Glove Sterilization and Use of Sterility Indicators, *J. Lab & Clin Med*, 19:382-390, 1934

⁶Report of the Chemical Laboratory of the American Medical Association, Paul Nicholas Leach, Director. The Sterilometer and the Aseptic Thermo-indicator, *J A M.A.*, 103:1621-1622, 1934

MATCHING OF COLUMN IN SATURATED STEAM

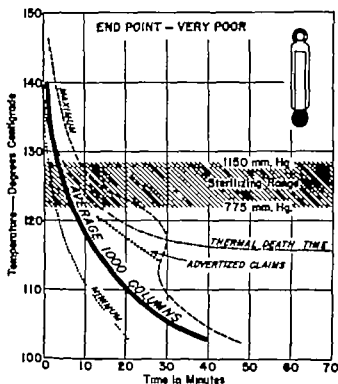


FIGURE 70

Walter ⁴

judged The control was but slightly affected by dry heat. The majority of the 1000 tested showed complete color change in less than six minutes, figure 70, and the average changed well below the advertised and published claims.^{4, 6} There was a sufficient number of delayed matchings to cause frequent needless resterilization

Investigation of the disappearance time of a lavender arrow (Aseptic Thermo-indicator) of chromium sesquichloride and the blending of its green isomer into a green background was made difficult by a poor end point. Despite the advertised 'snap' action of the indicator, the color faded progressively throughout the period following saturation with moisture with but rare exceptions. The majority of the 1000 tested indicated sterility in less than twelve minutes in the usual sterilizing range, figure 71, and the average changed below the reported and advertised 'snap' time.^{4, 7} This

¹ MAQATH, T. B. Positive, Inexpensive Method of Producing Sterile Goods, *Med Hosp.*, 41:112, Sept. 1933

DISAPPEARANCE OF LAVENDER ARROW IN SATURATED STEAM

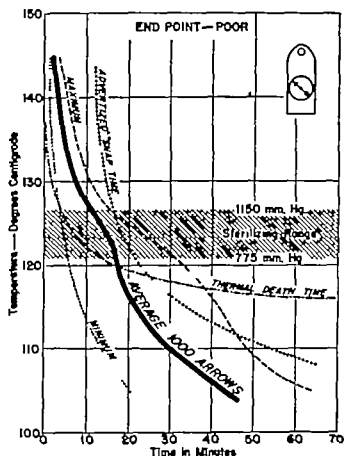


FIGURE 71

Walter ⁴

telltale was the most consistent performer of the three but there was a sufficient number of delayed changes to confuse attendants and to cause unnecessary resterilization

Similar, though less detailed, data have been compiled for "Steamclox."

The expense of certifying sterilization by telltale indicators, costing approximately three cents each, is not justified because of the disparity in individual performance in the commercial supply of each type of control. The large personal equation involved in the proper location and interpretation of this type of sterility indicator renders their use as a check on routine sterilization of dubious value for general hospital practice.

Many rely upon actually testing the

⁶ BRIDGES, L. C. On the Operation of a Workroom. With Special Reference to Sterilizing Processes Following a Three-Year Study *Hospitals*, 10:60-61 Oct. 1936.

efficiency of a sterilizer by running unannounced test cultures. This method gives accurate information only when an established technic is used. Because germination may be delayed in surviving organisms,² the information is not available until two to three weeks after the test so that the method is not applicable to the routine control of steam sterilization.

The most outstanding investigations on sterilization have been based upon bacteriologic studies on soil because it contains both aerobic and anaerobic sporebearing organisms which are resistant to heat. Because soils vary in the resistance of their bacteria to moist heat, it is essential to obtain uniformly resistant samples. This is readily done by drying garden soil in the air, powdering it, and exposing it to flowing steam in an Arnold Sterilizer for ten hours.¹⁰ The soil is then dried thoroughly in the air, subdivided into one-gram samples, and used for sterility tests after it has been established that control samples grow out when incubated in suitable culture media. To perform a test, the samples are most conveniently wrapped in filter paper packages. Such packages are used as sterility controls by introducing them in the densest portion of surgical packs. The test bundles are put in the lowest possible portion of the sterilizer and the sterilizer is operated in routine fashion. Following exposure to steam, the packages are removed with strict aseptic technic and their contents cultured. The cultures are examined at various intervals up to fourteen days. Unheated controls are cultured simultaneously and all negative

cultures are inoculated at the end of the incubation period to prove that the culture medium is effective.

Sterility tests are best conducted as described in the *Pharmacopœia of the United States*, Twelfth Revision, 1942, p 609

STERILITY TEST FOR LIQUIDS

When a test for the sterility of a liquid is prescribed, the following procedures shall be used:

Broth for Sterility Tests

Beef steak (freed of fat, tendons, and bone)	500 gm.
Peptone	10 gm.
Sodium Chloride	5 gm.
Distilled water, a sufficient quantity,	
To make	1000 cc.

Grind the beef steak in a meat grinder. Add 1000 cc. distilled water, mix well and allow the mixture to infuse in a refrigerator for not less than eighteen and not more than twenty-four hours. Remove it from the refrigerator, heat it in streaming steam at 100°C for one hour and then under a pressure of 15 pounds (121.5°C) for thirty minutes. Finally squeeze it through cheesecloth until the broth measures 1000 cc. If unable to obtain this amount by pressure, make up the volume with distilled water.

To 1000 cc of this broth add the peptone and sodium chloride and mix well until they are dissolved. Adjust the reaction of this mixture to a pH of 7.6. using normal sodium hydroxide and then heat in steam at 100°C for thirty minutes.

Again determine its reaction and, if necessary, adjust it with normal sodium hydroxide to 0.2 point above the specified pH. Now filter the product through a wet filter, transfer it to chemically clean containers, and finally sterilize the broth in an autoclave for twenty minutes at 15 pounds pressure.

The Test

To test for sterility pour this broth into Smith fermentation tubes or suitable substitutes so that each will contain not less than 25 cc.

¹ DIXON, E. C., BURKE, G. S., BECK, D. and JOHNSON, J.: Studies on the Thermal Death Time of Spores of *Clostridium Botulinum*. IV. Resistance of Spores to Heat and the Dormancy or Delayed Germination of Spores Which Have Been Subjected to Heat. *J. Infect. Dis.* 36:472, 1925.
² DIXON, E. E.: Sterilization Based on Temperature Analyzed and Time Ratio, *Mod. Hosp.*, 42:66, Feb. 1957.

of the nutrient broth and again sterilize at 15 pounds pressure for a period of thirty minutes. Finally incubate the tubes for a period of at least twenty four hours at 37 C.

To these tubes add 1 cc. of an aqueous, 1%, sterile dextrose solution for each 25 cc. of the broth, steam the tubes at 100 C for not less than thirty minutes and allow them to cool. The air liberated by the steaming must be removed from the tubes by tilting

Plant half of the tubes with 5 drops of the liquid to be tested and the other half with 20 drops of the same material.

Final readings for sterility shall be made after seven days of incubation at 37 C. When the liquid to be tested renders the test broth turbid, make transfers at the end of seven days from the tubes originally planted to others freshly steamed. These tubes to which the transplants have been made shall also be observed for seven days.

When the liquid in bulk containers is tested for sterility 10 cc. shall be planted from each container holding more than 1 liter and at least 3 cc. from each container holding less than 1 liter. When the product in final containers is tested, 3% of the total number shall be tested but the number need not exceed ten from any one lot of containers. Preservative, if present, shall be so diluted in planting that its activity does not exceed that of phenol in a dilution of 1:10,000.

If growth appears in any tube, the test shall be repeated, using double the number of tubes employed in the first test. If contamination is found, the liquid shall be discarded or treated in such manner as to render it free from living microorganisms.

STERILITY TESTS FOR SOLIDS

Broth for Sterility Tests under Aerobiosis

Beef steak (freed of fat, tendons and bone)	500 gm.
Peptone	10 gm.
Sodium Chloride	5 gm.
Dextrose	10 gm.
Distilled water a sufficient quantity	
To make	1000 gm.

Grind the meat. Add 1000 cc. of distilled water mix well, and keep cold in a refrigerator for from eighteen to twenty four hours. Remove, with a piece of absorbent cotton, any scum of fat which may be present. Then strain through cheese cloth and squeeze the meat as dry as possible. The amount of fluid recovered should almost equal the amount of water added. Alternative method Thoroughly mix the beef with the distilled water, heat at 100°C for one hour strain through cheesecloth, and press the meat as dry as possible.

Dissolve the peptone, sodium chloride, and dextrose in the liquid obtained by either method. Add sufficient normal sodium hydroxide so that the preliminary reaction, after diluting with distilled water to 1000 cc., is pH 7.6. Filter through a wet filter paper until clear, distribute it in quantities of 40 cc. each in chemically clean, preferably sterile, test tubes (approximately 25 mm. by 200 mm.) plug these with gauze-wrapped, nonabsorbent cotton and sterilize in an autoclave at from 15 to 20 pounds pressure (121.5 to 126.5 C) for from twenty to thirty minutes, or by any other suitable method. The final reaction should be between pH 7.2 and pH 7.4.

Do not use culture medium which has been kept longer than two weeks at room temperature or four weeks under refrigeration.

Broth for Sterility Tests under Anaerobiosis

Litmus Test Solution	10 cc.
Gelatin	20 gm.
Broth for Sterility Tests under Aerobiosis, a sufficient quantity	
To make	1000 cc.

The 'broth prepared for aerobiosis' need not be filtered or sterilized before the addition of the other ingredients. Dissolve the gelatin in the broth with the aid of gentle heat, add the litmus T. S. and adjust the preliminary reaction to pH 7.6. Then, if necessary add the albumen of two fresh eggs or its equivalent in desiccated egg albumen, heat to coagulate, and add distilled water to make 1000 cc., filter until clear and distribute the filtrate in quantities of 40 cc. each, as described under the broth for testing aerobic organisms. Sterilize

in an autoclave at from 15 to 20 pounds pressure (121 5° to 126 5°C) for from twenty to thirty minutes, or by any other suitable method. The final reaction should be between pH 7.2 and pH 7.4.

The 10 cc of litmus T S may be replaced by 0.2 gm of azolitmin if preferred.

Do not use culture medium which has been kept longer than two weeks at room temperature or four weeks under refrigeration.

Honey Medium for Molds and Yeasts

Peptone	10 gm
Honey	60 cc
Distilled water, a sufficient quantity,	
To make	1000 cc

Dissolve the peptone in the distilled water with gentle heat, add the honey, and adjust the preliminary reaction to pH 6.0. Filter if necessary and sterilize in an autoclave at from 15 to 20 pounds pressure (121 5° to 126 5°C) for from twenty to thirty minutes or by any other suitable method. The final reaction should approximate pH 5.6.

Sterilized Distilled Water

Distribute distilled water in quantities of 40 cc each in chemically clean, preferably sterile, test tubes. Plug the tubes with gauze-wrapped, nonabsorbent cotton, and sterilize in an autoclave.

INACTIVATING FLUIDS FOR INACTIVATING BACTERIOSTATIC AGENTS

Fluids A and B are used for removing the various chlorine, iodine, or mercury compounds which are employed as bacteriostatic agents in the tubing fluids used in the packaging of sutures. Fluid C is necessary as a preliminary inactivating fluid if the chemical analysis shows that the sutures contain copper salts. If bacteriostatic agents, other than those above designated are used, appropriate sterile inactivating fluids and appropriate sterile washing agents must be employed so as to remove effectively the bacteriostatic and inactivating agents, which it present would interfere with bacterial growth in the subsequent test for sterility.

Inactivating Fluid A

Sodium Thiosulfate	10 gm.
Sodium Carbonate	10 gm
Distilled water, a sufficient quantity,	
To make	1000 cc

Mix, filter if necessary, and distribute in quantities of 40 cc each, in chemically clean, dry, sterile test tubes. Sterilize in an autoclave at from 15 to 20 pounds pressure (121 5° to 126 5°C) for from twenty to thirty minutes.

Inactivating Fluid B

Sodium Thiosulfate	100 gm
Distilled water, a sufficient quantity,	
To make	1000 cc

Mix, filter if necessary, and distribute in quantities of 40 cc each, in chemically clean, dry, sterile test tubes. Sterilize in an autoclave at from 15 to 20 pounds pressure (121 5° to 126 5°C) for twenty to thirty minutes.

Inactivating Fluid C

Ammonium Chloride	50 gm
Stronger Ammonia Water	15 cc
Distilled water, a sufficient quantity,	
To make	1000 cc

Dissolve the ammonium chloride in enough distilled water to make 1000 cc, filter if necessary, and sterilize in an autoclave at from 15 to 20 pounds pressure (121 5° to 126 5°C) for from twenty to thirty minutes. Add 15 cc. of stronger ammonia water, and distribute the solution aseptically in quantities of 40 cc each, in chemically clean, dry, sterile test tubes.

Petrolatum-paraffin Mixture for an Anaerobic Seal

Petrolatum, having a melting point of 48°C	50 gm.
Paraffin, having a melting point of 57°C	50 gm.

Liquefy the ingredients by gentle heat, mix, and distribute, preferably in quantities of 50 or 100 cc each, in chemically clean, dry test tubes or other containers. Sterilize in a hot-air oven at 170°C for two hours or by any other suitable method.

SUGGESTED TECHNIQUE FOR CONDUCTING TESTS FOR STERILITY

Carry out all bacteriological tests under the most rigid aseptic conditions. Wherever possible,

tests should be carried out by two operators working together. The outside wearing apparel of the operators should consist of sterile caps, gowns, and face masks to cover the nose and mouth, and all manipulations should be conducted in a small, dust proof room supplied with filtered air under positive pressure. The air in the testing room should be sprayed with water and the room itself washed with a disinfectant each time transfers are to be made, or at least once daily when in use, the room being allowed to remain closed for fifteen minutes thereafter.

Opening Packages and Containers

For Purified Cotton, Gauze, Surgical Dressings, and Related Products. — Flame with care the carton, package, container or one of the margins if in an envelope, to remove adhering dust particles. Remove material from the package with sterile forceps. Sterilization of the latter is effected in an autoclave or by wrapping the forceps and heating them in a hot-air oven at 170 C for two hours. Between successive transfers thoroughly flame the forceps. If scissors are needed, sterilize them by the technique directed for forceps.

For Sutures. — If necessary make a file line in the center of the tube or about 10 mm. above any tubing fluid. Then place the tubes in a suitable, active disinfecting solution for twenty-four hours. Remove the tubes with sterile forceps and place them between sterile towels. As an alternative method of sterilization, flame the tubes, preferably in a wing flame, avoiding the heating of the contents.

Removing and Culturing Contents. — Take portions of the substance in triplicate from the cartons, wrapped packages, envelopes, and similar containers. The material to be tested should be taken from various locations within the roll of purified cotton, gauze, surgical dressing or related material, preferably from the outer end, center and core, using sterile instruments and equipment. Transfer these portions of the material as rapidly as possible to the necessary number of tubes of medium for aerobic and anaerobic culturing, and also

to tubes of honey medium for detecting molds and yeasts. Before use, heat and culture medium for anaerobiosis at 100 C for fifteen minutes and cool quickly. Seal the inoculated anaerobic medium with a thick (3 cm.) layer of sterile petrolatum paraffin mixture. Place the sealed tubes immediately in a 37 C incubator or in a cool water bath to solidify the seal. The time between the removal of the medium from the steam bath and the pouring of the seal should not exceed fifteen minutes when examining sutures, and thirty minutes when examining other solids. Cultures of sutures are incubated at 37 C for fifteen days before negative results are recorded. Other products are to be incubated as directed above for seven days before negative results are recorded. The cultures in honey medium for yeast and fungi are to be incubated for fifteen days at from 22 to 25 C before negative results are recorded.

In the case of sutures, break the tube at the filed line preferably by holding against it a red hot, curved wire. Transfer the entire suture or loop or strand of gut, with the points of the sterile forceps, to the test tube containing 40 cc. of sterile distilled water. Replace the cotton plug and incubate the tube at 37 C for twenty-four hours. Then transfer the gut to a test tube containing 40 cc. of sterile inactivating fluid A, using the necessary precautions to prevent contamination, and again incubate at 37 C for twenty-four hours.

If chemical analysis of at least four sutures of any lot reveals that the sutures are impregnated with more than 2% of a mercury compound or more than 5% of chlorine or iodine compounds, use sterile inactivating fluid B instead of the above. If the sutures upon chemical analysis have been found to contain copper, transfer the suture, after treatment with 40 cc. of sterile distilled water to 40 cc. of sterile inactivating fluid C and again incubate at 37 C for twenty-four hours.

It may also be necessary to employ other appropriate sterile inactivating fluids if bacteriostatic agents other than mercury iodine, or chlorine compounds have been used. If inactivating fluid B or inactivating fluid C, or

special inactivating fluids are used, follow by placing the suture in 40 cc. of sterile inactivating fluid A. That the inactivating fluid used may not interfere with bacterial culturing, an additional step is necessary before the transfer of the suture to the culture medium. This is to wash the suture, after treatment with the inactivator, in another tube of 40 cc. of sterile distilled water. Finally place the suture in each of the three tubes of medium to test for aerobes, anaerobes, and for molds and yeasts as detailed above.

Confirm all positive cultures showing growth, by a microscopic examination of stained smears.

At the end of the period of incubation inoculate at least 5% of all negative aerobic suture cultures showing no growth, with 1 cc. of a 1:100,000 dilution of an 18- to 24-hour broth culture of *E. coli* and incubate at 37°C for three days. Inoculate at least 5% of all negative anaerobic suture cultures showing no growth with 1 cc. of a 1:100,000 dilution of an 18- to 24-hour broth culture of *C. novyi* and incubate at 37°C for three days. Inoculate at least 5% of all negative yeast and mold suture cultures showing no growth, with 1 cc. of a 1:1000 dilution of a 72-hour honey medium culture of *Monilia albicans* and incubate at from 22° to 25°C for three days. Failure of growth is evidence that bacteriostatic agents which may have been carried over in the transfer are present.

CONTROLS

Tubes of media, distilled water, and inactivating fluid are preferably placed in cans or baskets before sterilization and then covered by paper hoods. Incubate all tubes of culture media immediately after their preparation, for forty-eight hours at 37°C and then for forty-eight hours at room temperature. Discard tubes showing growth. Culture aerobically and also anaerobically 10 cc. of the distilled water used in these tests and also each of the inactivating fluids, immediately after their preparation. If any of the tubes used in testing show growth the entire stock of material they represent must be discarded.

When testing any material for sterility, the following controls are to be conducted simultaneously:

a. Inoculate two tubes of each of the culture media to be used with 10 cc. of the distilled water used and incubate for fifteen days.

b. Carry out a similar test as in (a) but replace the distilled water with the inactivating fluid used. If more than one inactivating fluid is to be employed, each one must be tested separately.

c. Seal two tubes of the anaerobic culture medium with a 3 cm. layer of the petrolatum-paraffin mixture and incubate for fifteen days to determine the sterility of the anaerobic seal.

d. The culture medium to be used for anaerobic culturing should support growth upon inoculating 40 cc. with 1 cc. of a 1:100,000 dilution of an 18- to 24-hour broth culture of *C. novyi*. The culture medium to be used for aerobic culturing should support growth upon inoculating 40 cc. with 1 cc. of a 1:100,000 dilution of *E. coli*. Incubate inoculated tubes for seventy-two hours at 37°C. The culture medium used for molds and yeasts should support growth upon inoculating 40 cc. with 1 cc. of a 1:1000 dilution of a 72-hour honey medium culture of *Monilia albicans* and incubating at 22° to 25°C for three days.

Attempts to test sterility by a less detailed technic yield results that are misleading. Even though negative results are obtained by careful bacteriologic work, it must be realized that such tests only indicate sterility of the samples actually tested. Figures 47 and 55 illustrate how little negative cultures signify unless all the factors concerning packaging, loading, and operation of a sterilizer are considered. For routine control of sterilization, these details must be built into the technics for preparing supplies and instruments for operation. They must constantly be drilled into the personnel responsible for the loading and operation of the sterilizers. Control of the process as a whole then becomes a problem in inspection.

and adherence to standards to insure sterility of all of the supplies and instruments. Foolproof technic, trained personnel, and safe

physical minima of time and temperature are more desirable and practical in hospital practice than periodic bacteriologic tests.

CHAPTER IX

STERILIZATION BY DRY HEAT

. . . that by exposure to a temperature not below 200° Fahr. during at least one hour, the contagious matter of scarlatina is either dissipated or destroyed . . . that the disinfecting agency belongs to heat alone.

— WILLIAM HENRY, M.D., F.R.S., 1832¹

The use of dry heat is limited to the sterilization of articles which do not withstand the corrosive action of steam, anhydrous objects which are spoiled by moist heat, and anhydrous substances which prevent the bactericidal action of moist heat. Cutting edge instruments, surgical gut, ground glass, and dry chemicals such as, greases, oils, glycerine, are examples.

Dry heat has definite limitations which make its application either difficult or time-consuming.² When dry heat is used at sufficiently high temperatures to shorten the sterilizing period, fabrics and rubber goods are destroyed.* Because heating is by conduction, penetration is slow, figure 46, as compared with the rapid heating by convection of steam into bundles. The application of dry heat in a sterilizer is difficult to control because the density of air decreases rapidly as it is heated and stratification persists unless a fan insures mixing or the walls of the sterilizer are heated to uniform temperature. Even with proper sterilizer

design, the temperature is likely to vary widely throughout the load because the specific heat of air is low and it is a relatively poor heat transfer agent.³ If the temperature is raised to shorten the sterilizing period, great care must be taken to obtain accurate control, otherwise the temper of instruments may be drawn because the critical temperature for steel is but little higher than the temperature often used for reasonably rapid sterilization.⁴

STERILIZATION BY DRY HEAT

The thermal death time for resistant dry spores at various temperatures is shown in figure 72.⁵ The effect of but a small percentage of water (less than 0.5%) in decreasing the period of exposure is obvious. Note how sharply it contrasts with figure 37 both as to the degree of heat required to destroy bacterial life and the prolonged exposure which is necessary. The latter is not quite a true picture because the period for heating the articles to sterilizing temperature is

¹ HENRY, W. Further Experiments on the Disinfecting Power of Increased Temperatures, *Philosophical Magazine*, 11:22, 1832

² KOCH, P. and WOLFFHUGEL, G. Untersuchungen über die Desinfektion mit heisser Luft, *Mitt. d. Kaiserl. Gesell.*, 1:1-21, 1881.

* Cotton fibers char at 299°C

³ HALLER, E. and HEICKE, K. Die Prüfung von Laboratoriumsgeräten für die Wasserdampf- und Heissluftsterilisation, *Zentralbl. f. Bakt.*, Abt. I, 114:376, 1929

⁴ JEFFRIES, Z. and ARCHER, R. *The Science of Metals* New York: McGraw-Hill, 1924, p. 432

⁵ RODINSKY, H. Ueber die thermische Sterilisation Wasserfreistoffe usw., *Arch. f. Hyg.*, 109:67, 1933

THERMAL DEATH TIME OF SPORES IN DRY HEAT

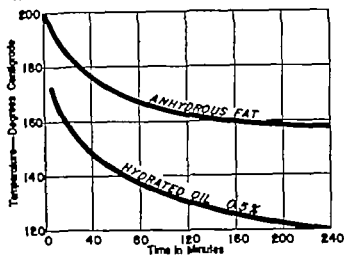


FIGURE 72 *Rodnbeck*

much longer than that when steam is the heating agent. It takes seventy minutes for 30 cc. of petroleum jelly on 30, 5 cm X 15 cm., layers of 40 X 42 gauze in a shallow metal container to reach 160°C, figure 73. One hundred sixty additional minutes are necessary to destroy spores in the gauze, figure 72.

There are four types of dry heat sterilizers which can be used in the operating room. The conventional hot air oven, such as is used by bacteriologists for sterilization of glassware, is the type most frequently used, figure 74, 1. The chief fault is that most of these ovens heat unevenly and slowly and sterilization cannot be depended upon unless the sterilizer has been studied carefully and the period necessary to heat the sterilizer and its contents throughout is accurately known. In addition, the character of the material that surrounds the organisms must be known because, as can be seen in figure 72, the microbicidal action of dry heat is influenced by the type of fluid which contacts the organism. The majority of such sterilizers can be operated at 160°C and the sterilizing period is one hour after the whole load has come to temperature, PROVIDED instruments are clean and free from oil or grease. If the latter are present,

HEATING PERIOD ON HOT PLATE

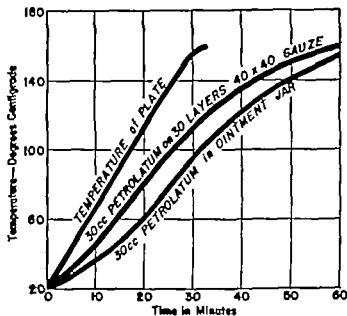


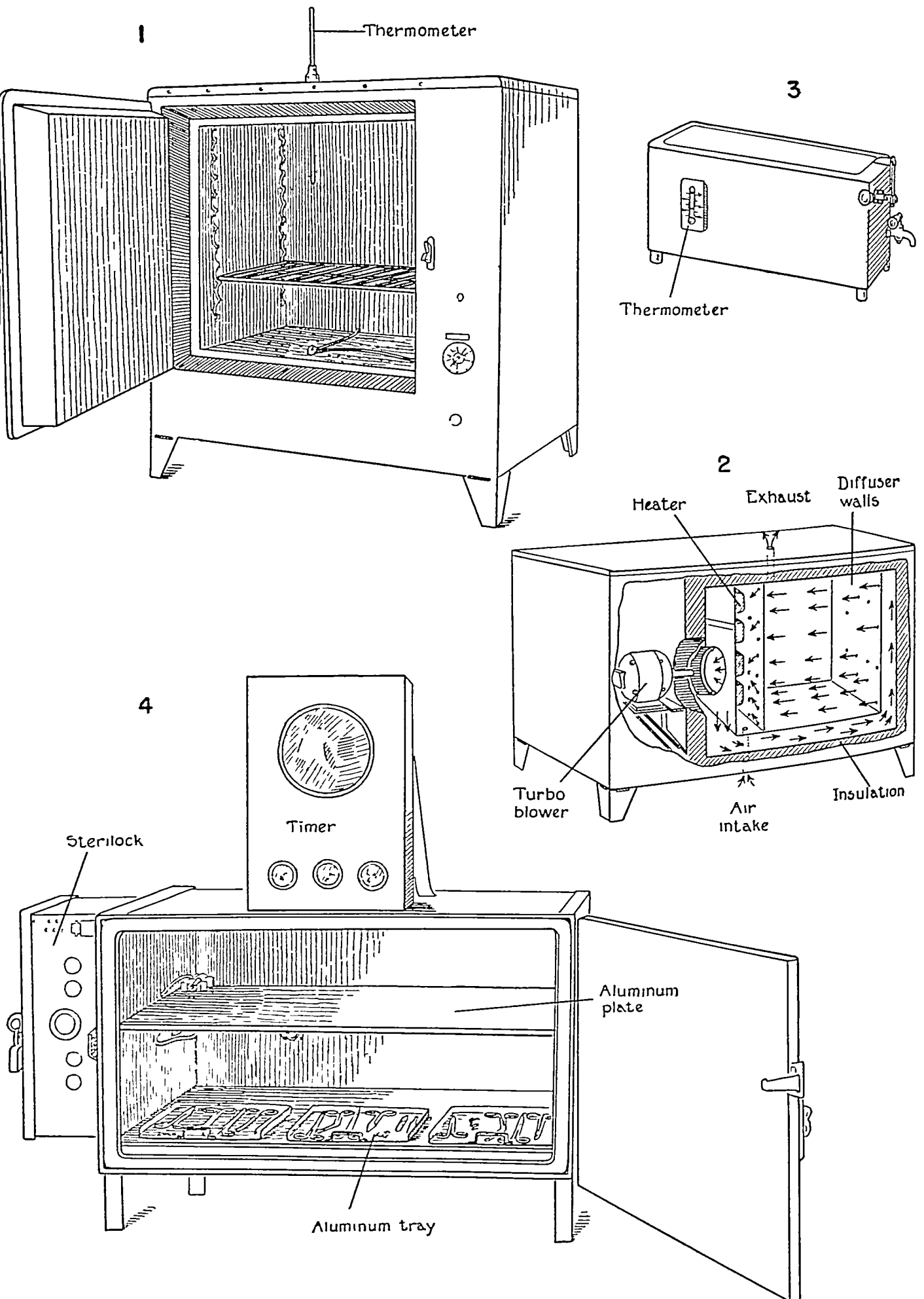
FIGURE 73

safe sterilization calls for four hours' exposure at 160°C. Forced circulation of the air in a hot air oven, as by a blower, figure 74, 2, hastens heating and assures uniform conditions throughout.

Another class of dry heat sterilizer uses oil as the heating agent. The usual kind found in hospitals is quite similar to the small instrument sterilizer used in doctors' offices, figure 74, 3, for sterilizing instruments in boiling water, except that oil is substituted for the water and the temperature is maintained at 160°C instead of the usual 100°C. They are quite satisfactory when used carefully but as used in the average hospital, they are messy, smelly, and hazardous, both from the point of view of being a fire hazard and a potential source of scalding. As indicated in figure 72, the exposure is three hours at 160°C.

Surgical gut is usually sterilized by dry heat in an oil sterilizer because moisture would hydrolyze the protein and destroy the gut. Surgical gut is made by stripping the submucosal layer of sheep's intestines free from mucosa, muscularis, and serosa. The strips of submucosa are then tanned

TYPES OF DRY HEAT STERILIZERS



and twisted into strands. These strands are sized and polished and finally wrapped on reels and inserted into glass tubes. They are sterilized after dehydration by immersion in cumol or high flash naphtha at 160°C for one hour. After sterilization has occurred, the cumol is drained off and a sterile tubing fluid containing a small percentage of water is substituted. Ninety five per cent alcohol is a common tubing fluid. The tubes are then sealed. The water in the tubing fluid is absorbed by the surgical gut, making it more supple. Heat destroys non-boilable gut because it causes hydrolysis. The difference between boilable and non-boilable surgical gut is that in the former, cumol is sealed in the glass tubes with the anhydrous gut so that the whole tube can subsequently be resterilized by heat without hydrolyzing the gut.

A clean, convenient, readily controlled dry heat sterilizer makes use of electrically heated aluminum plates as shelves, figure 74, 4.* Because the aluminum conducts heat quickly, good heat distribution and accurate thermostatic control are possible. The load is heated evenly because the instruments actually contact the hot aluminum plate.

The most convenient way of using this sterilizer is to fit an insulated cabinet with the control illustrated in figure 65 so that the sterilizer can be loaded and run at night. The exposure for clean, oil-free instruments is 160°C for one hour. If the instruments have been oiled or are greasy, it takes three hours at 160°C to insure sterilization. The "Sterilock" control turns off the electric current when sterilization is complete and the sterilizer cools to the point where the instruments can be handled safely before the door is unlocked.

Every dressing sterilizer can be modified for use as a dry heat sterilizer by inserting a thermometer in the jacket return line to indicate the temperature of the jacket accurately. When steam pressure of 775 mm. Hg is carried in the jacket, the chamber walls are uniformly heated to 121°C and after the door has been shut to stop air currents, ideal conditions for sterilization by dry heat prevail. The chief handicap is that the sterilizing period at 121°C is four hours, provided no oil is present. Nevertheless, such a sterilizer can be loaded with clean cutting-edge instruments or powdered chemicals, the melting points of which are higher than 121°C, and steam pressure maintained in the jacket. Reliable sterilization can be depended upon if the load is exposed all night.

The sulfonamides are conveniently sterilized for topical application by measuring small quantities (2.5 gm.) into test tubes and stoppering them with a cotton plug held in place with a flask hood. The tubes are sterilized as described in the preceding paragraph. When the flask hood is removed, the plug can be pulled out carefully to leave a sterile lip over which the powdered drug can be spilled without danger of contamination.

If a sterilizer carrying steam in the jacket at 1400 mm. Hg gage pressure is available, oil-free objects can be sterilized safely by two hours' exposure to dry heat at 132°C. Instruments and small articles can be arranged on a rack where they are quickly heated to sterilizing temperature by radiant energy.

SANITIZATION BY DRY HEAT

Dental instruments, such as hand pieces or burrs, present a special problem in sanitization. Bacteriologically, the usual dental technic is not aseptic nor is it performed in a disinfected field, but terminal disinfection

*WALTER, C. W. *Sterilization, Surgical Clinics of North America*, New York, April, 1942.

is desirable to avoid spread of infection from patient to patient. The corrosive action of moist heat must be avoided to keep gears running smoothly and burrs cutting cleanly. The destructive action of moist heat on these instruments causes such a high maintenance charge that many prefer not to disinfect the instruments at all.⁷

These instruments can be cleaned immediately after use by operating them in a cleaning solution of the following.

xylol	200 cc
carbon tetrachloride	200 cc
liquid petrolatum USP	400 cc

The cleaned instruments are then immersed in liquid petrolatum USP (heavy) and heated to 121° C in a sterilizer designed for the purpose. The period of exposure is two minutes when only a few instruments are sanitized. When many instruments are put in the sterilizer, a period sufficiently long to permit the oil to regain its temperature of 121° C is necessary. The thermal death time for wet vegetative bacteria in

oil at 121° C is 50 seconds.⁸ The two minute exposure provides an adequate factor of safety. The instruments are removed from the sterilizer with a dry transfer forceps and placed in a suitable container to cool and drain. Residual oil can be removed by wiping the sanitized instrument with a freshly laundered cloth. The transfer forceps must be dry because moisture causes spattering of the hot oil due to the explosive ebullition of steam and combustible germicides carried on the forceps. Alcohol, for example, may cause flash fires.

CHARRING

Actual charring is another method of applying heat for the destruction of bacterial life. The microbicidal action of charring may be by actual burning of the bacteria when a dry object, such as a culture tube, is held in a Bunsen flame for a period not less than twenty seconds. Usually, however, a combination of dry and moist heat acts to destroy bacteria. The actual cautery, for example, generates steam in the appendiceal stump and only burns the tissue after it has been dehydrated. The same is true of the desiccating current applied by the fulgurating needle or radio scalpel.

⁷ Parke, G. L.: Sterilization and Lubrication of Dental Hand Pieces, *U. S. Nav. Med. Bull.* 71:955-959, 1945
⁸ Parke, G. L.: Sterilization Effectiveness of a Hot Oil Bath, *J. Dent. Res.* 25:89, 1946

CHAPTER X

STERILIZATION OF DRESSINGS AND DRY GOODS

Surgeons are constantly encountering problems of sepsis, asepsis and antisepsis. In spite of this fact, there are too many surgeons who know too little about bacteria and their habits. Without asepsis practically the whole field of elective surgery would collapse.

— M. M. ZINNINGER, 1943¹

The routine sterilization of dressings and dry goods presents problems in addition to those discussed in Chapters VII and VIII. The dry goods must be packaged so that they can be handled by unsterile individuals and stored until needed. The wrapper must permit ready penetration by steam, yet must be mechanically tight so that careless fingers or vermin are excluded. Ideally, the package should be sufficiently large to contain the supplies for a surgical procedure stacked in such fashion that when the package is opened, the contents present in the order in which they are used. This is important because it avoids the long pre-operative set up during which supplies are exposed to air borne contamination and subjected to repeated handling while they are being rearranged to suit the convenience of the scrub nurse. Finally, the wrapper must provide a sterile field for the contents when it is opened by an unsterile individual.

To satisfy bacteriologic requirements, the period required for steam to penetrate the largest bundle must be known. This factor is as important as determining the quality of steam being used in the sterilizer because

the best microbicide is useless unless it actually contacts all the bacteria in the package. To insure sterilization of dry goods, rigid standardization of packaging must be enforced; otherwise, the most conscientious operation of the sterilizing equipment itself is futile.

A good example of such standardization is the laparotomy kit, figure 76, 8. The kit weighs 8.6 kg. and is wrapped in a single package, 55 × 33 × 22 cm., in such a manner that saturated steam contacts the entire contents within fourteen minutes after the temperature in the exhaust line rises to 121°C, figure 59. The size, shape, and internal arrangement of the package contribute to this result.

The general principles of packaging the laparotomy kit are depicted. The wooden trough, figure 75, 1, limits the size and shape of the package to standard dimensions which permit uniform penetration. It also yields a package which fits the sterilizing carriage best, figure 103, 2. The wrapper is made from two single bed sheets (160 × 228 cm.) folded crosswise and interleaved pamphlet-like to form four thicknesses, 160 cm. long and 120 cm. wide, figure 75, 4. The package is tied with three meters of no. 1 awning line applied as a library tie. The cord is

¹ Zininger, M. M. Editorial, *Bacteria and the Surgeon, Surg., Gyn. & Obs.*, 76:635, 1943. By permission *Surgery, Gynecology & Obstetrics*.

prepared by throwing a simple overhand knot at one end to prevent fraying. A loop knot with a loop 7 cm long is bent on the other end, figure 75, 2. The wooden trough is then placed on a nurse's table in the identical position in which the stack of sterile goods is wanted at operation. The cord is placed in the bottom of the trough with the loop protruding roughly 60 cm from the left of the trough, figure 75, 3. The folded sheets are next draped in the trough with the folded edge away from the operator and the shortest leaves of the sheets uppermost, figure 75, 5. The sheets should be arranged in the trough so that the whole table is covered, figure 75, 6, 7. They will then serve as sterile drapes when the package is opened, figure 142. The supplies needed during the operation (sponges, abdominal packs, additional towels, final dressings) are arranged on the bottom layer, figure 76, 9. Those required earlier are put on top. The laparotomy sheet, fan-folded and rolled to afford easy draping, as shown in figure 79, is put in the center of the second layer, figure 76, 10. This sheet is the key to successful sterilization because when properly folded and rolled, and suitably located in the bundle, it provides channels for ready penetration of steam to the center of the bundle and thus it subdivides the larger package into five small sections, figure 76, 8. Three folded gowns are piled to the right of the laparotomy sheet, figure 76, 11. The nurse's gown is placed on top of the towels to the left of the rolled sheet. Towels, folded for draping the skin, figure 96, 1-6 are piled on top of the laparotomy sheet and the bundle is snugged together, figure 76, 12.

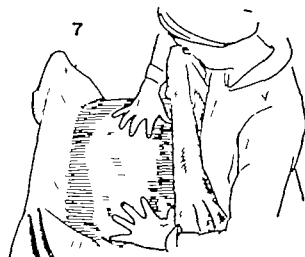
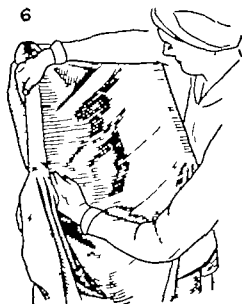
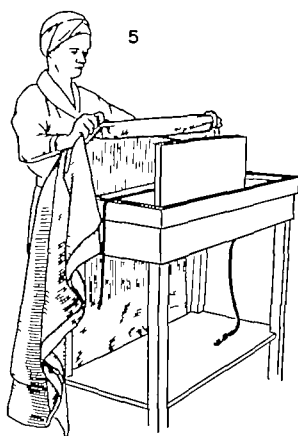
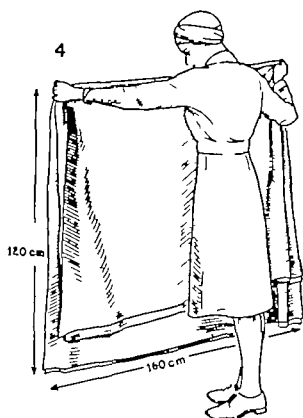
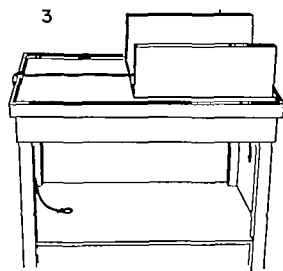
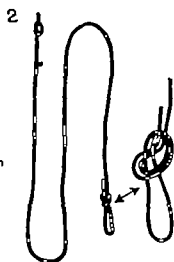
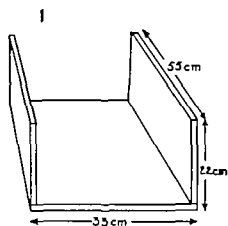
The two uppermost leaves of the wrapper are brought across the top of the bundle, figure 76, 13, and 77, 18*b*, and a small cuff is turned back 76, 14 to provide a safe fingerhold for the unsterile nurse as she unwraps the kit, figure 142, 5. The folded edge of the

wrapper is then pulled toward the operator and the edge is cuffed back as it is tucked into the crevice between the pile of supplies and the lower leaves of the wrapper, figure 77, 15 and 18*c*. The outer leaves of the wrapper are brought over to finish the package, figure 77, 16, 17. The interdigitating layers of wrapper insure against accidental contamination by careless hands or prowling vermin because anything inserted beneath the outer leaves is put into the cul-de-sac between the folds of the inner sheet, figure 77, 18*d*. The bundle is completed by folding in the end flaps just as with any paper-wrapped package, figure 77, 19, 20, 21. The two ends of the cord are picked up in either hand, figure 78, 22, and crossed in the center of the package. The loop is then caught over the left thumb and the long end held in the right hand, figure 78, 23, and as the package is lifted from the trough, the long end is carried about the package, figure 78, 24, 25, and inserted through the loop, figure 78, 26. The cord is pulled tight and a single bow knot is tied, figure 78, 27, 28, 29. The kit is then labeled with a soft pencil,* figure 78, 30. If the package is properly wrapped, it can be opened by an unsterile nurse without danger of contamination because the wrapper opens out from the sterile field and its contents are instantly available in the order in which they are required during operation.

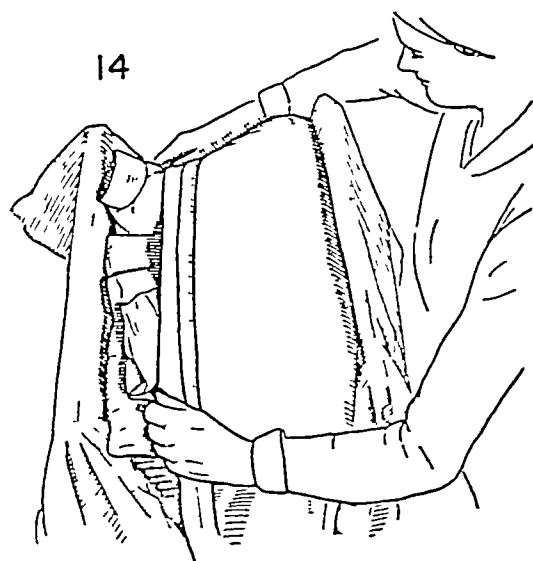
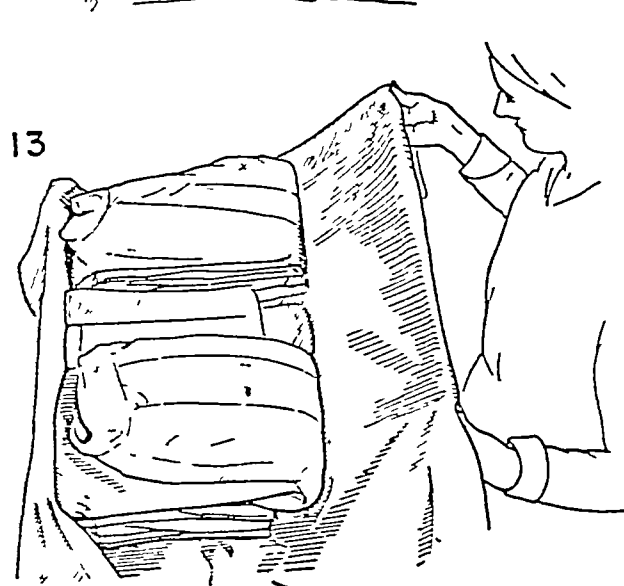
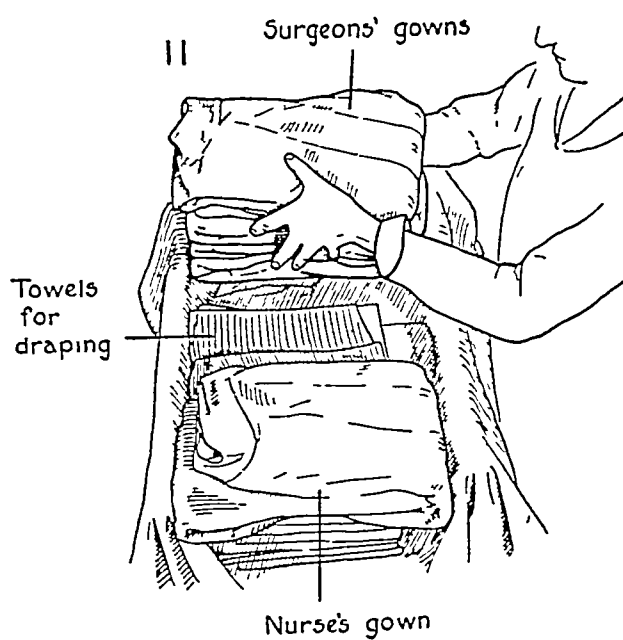
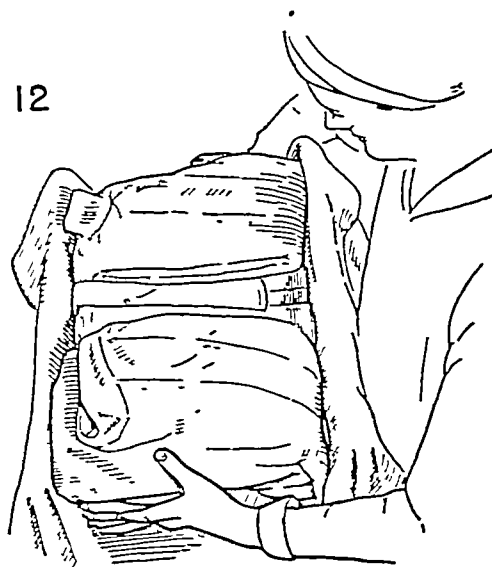
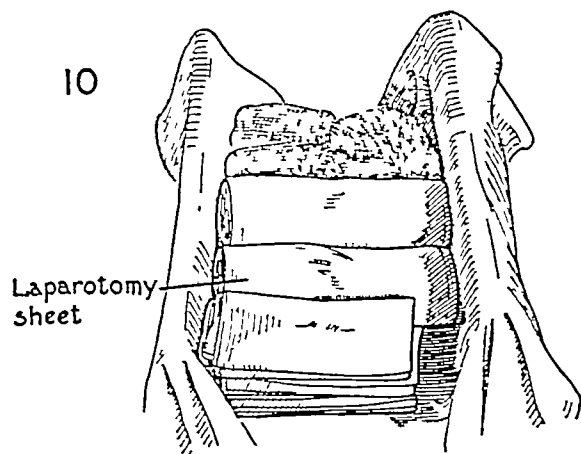
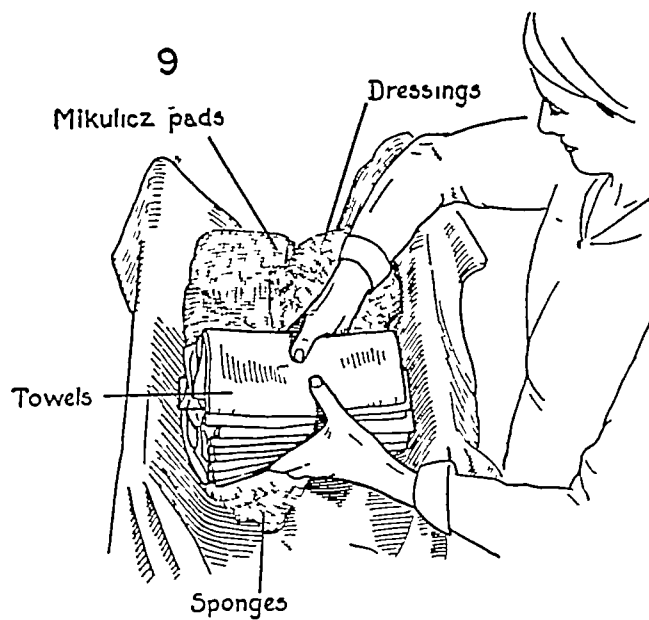
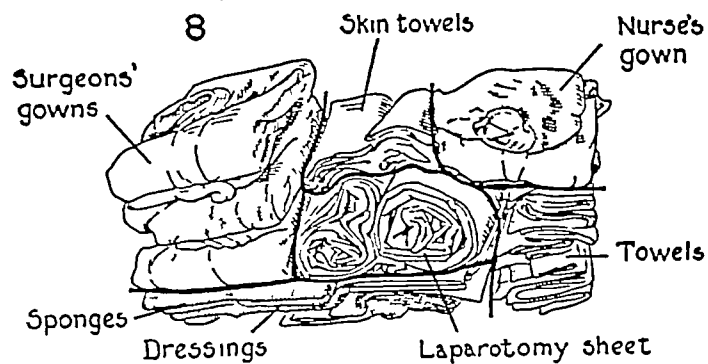
The use of ties rather than pins is desirable because the life of the cloth wrappers is prolonged and pinholes which invite contamination are avoided. It also prevents tight wrapping which makes penetration difficult for steam. No 1 awning line has been found most suitable for large packages, while spool tape has been found more economical and satisfactory than twine for small packages.

* "Venus" 6B, American Pencil Company

PREPARING WRAPPER FOR LAPAROTOMY KIT

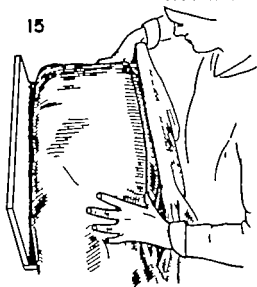


ASSEMBLING SUPPLIES FOR LAPAROTOMY KIT

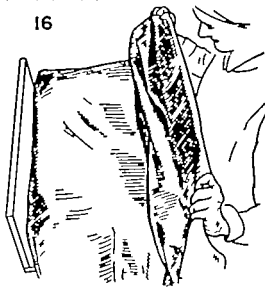


WRAPPING LAPAROTOMY KIT

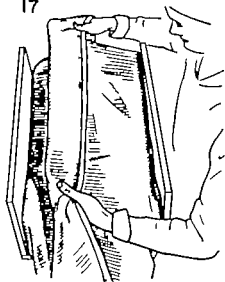
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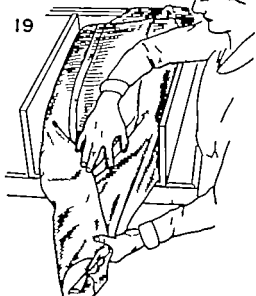


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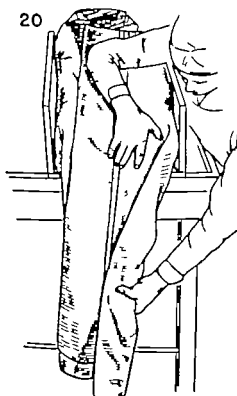


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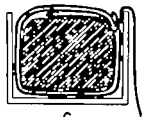
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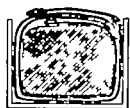
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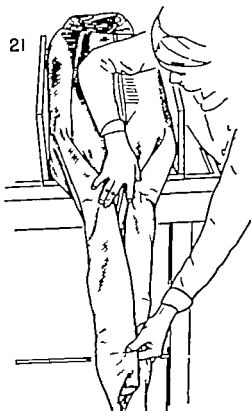


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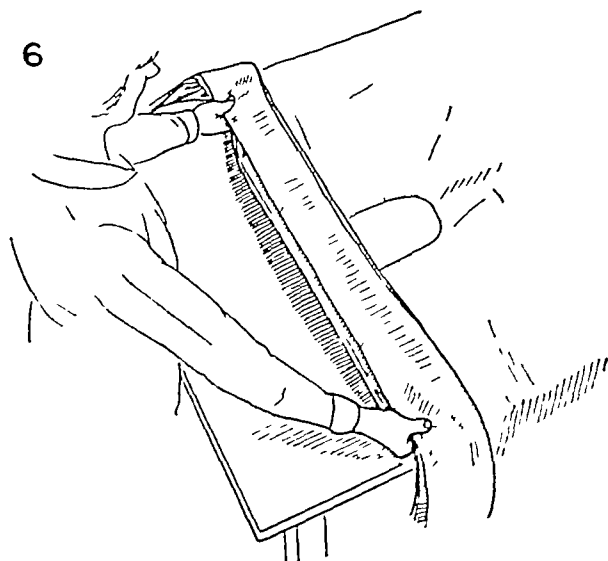
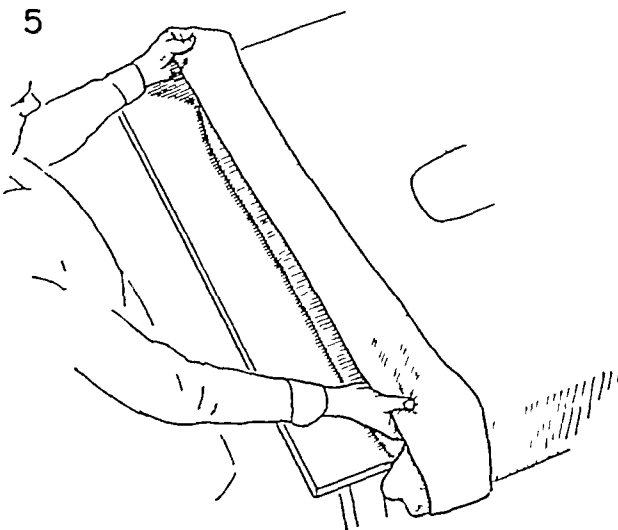
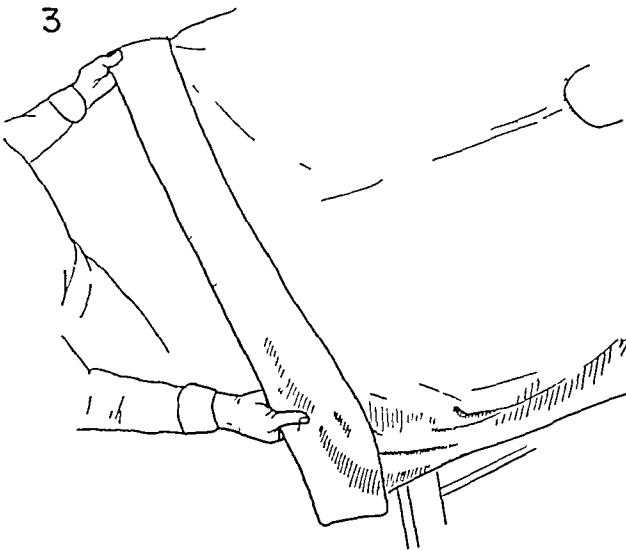
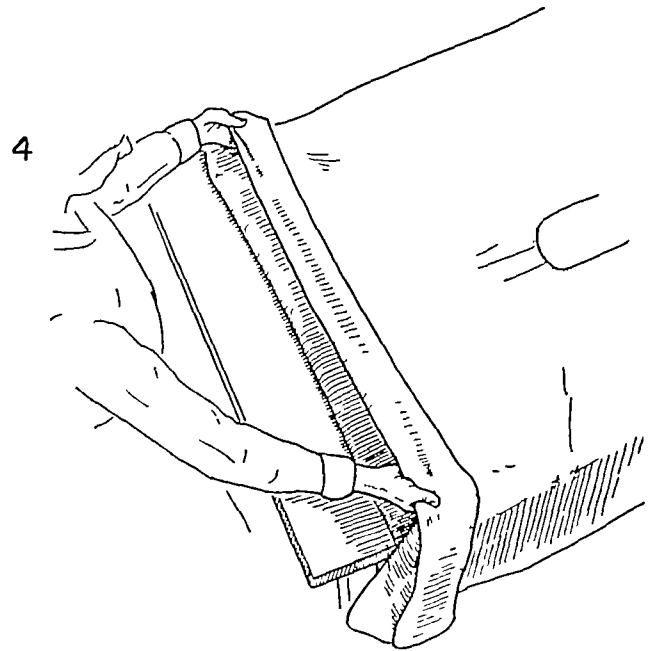
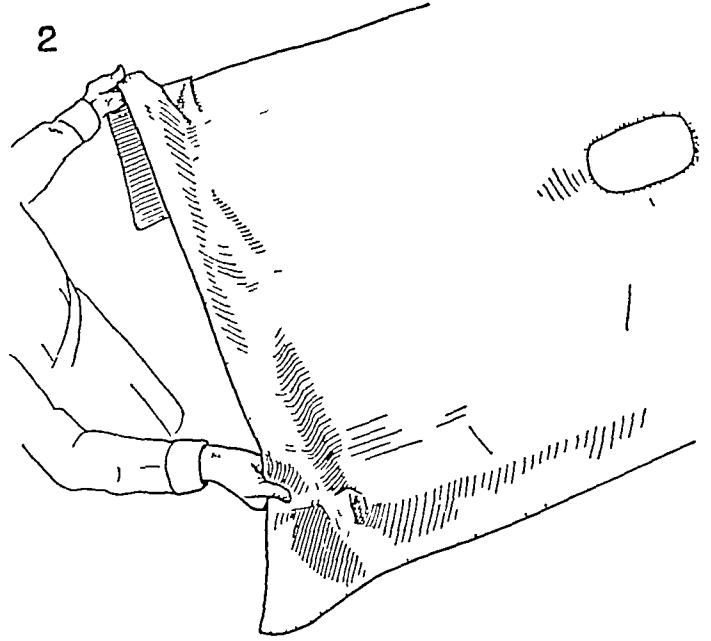
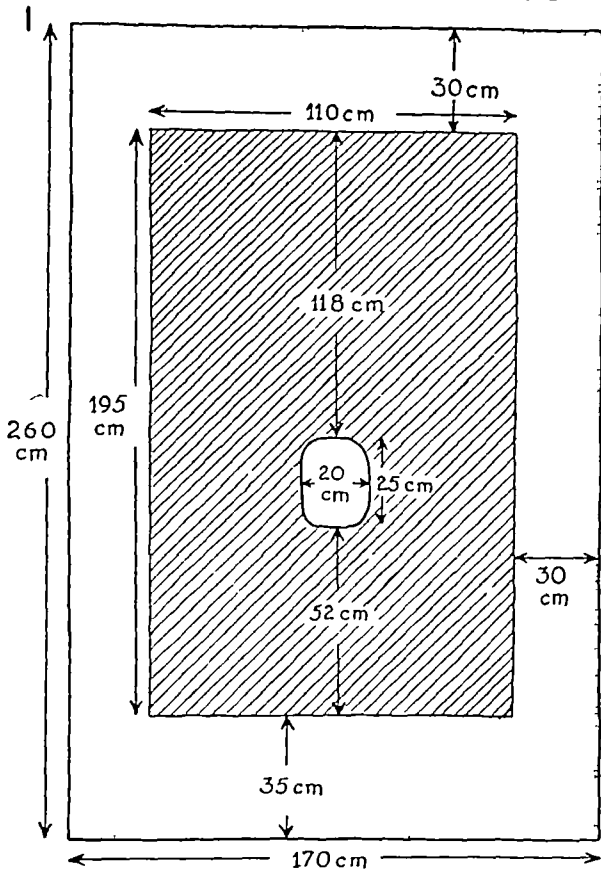


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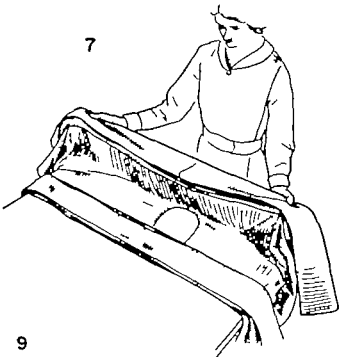


FOLDING LAPAROTOMY SHEET

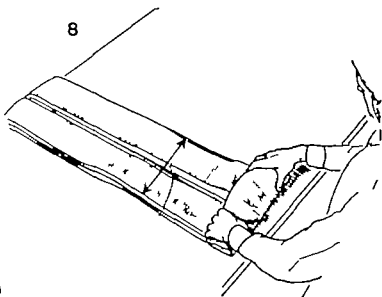


ROLLING LAPAROTOMY SHEET

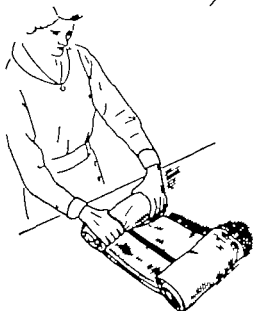
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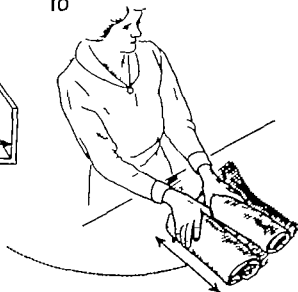
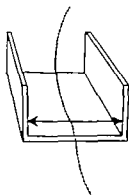
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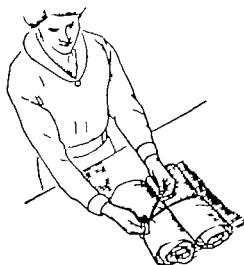
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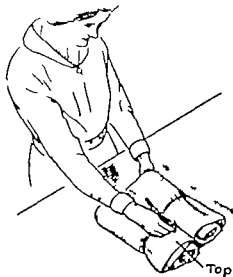
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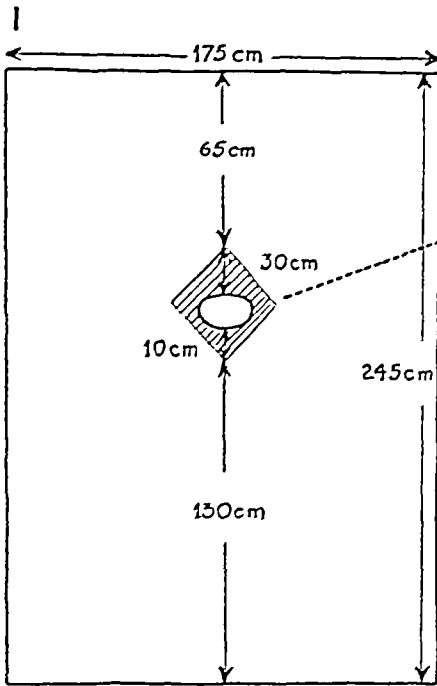
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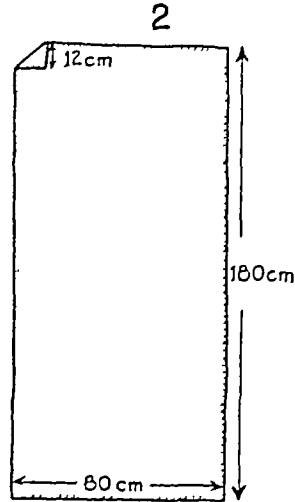
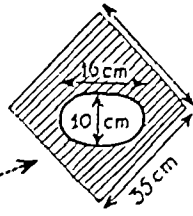
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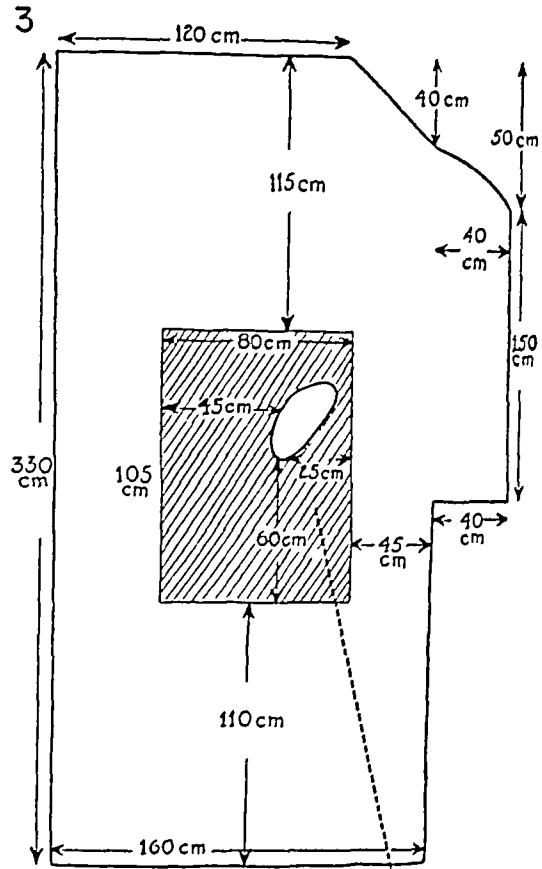
PLANS FOR SURGICAL DRAPE



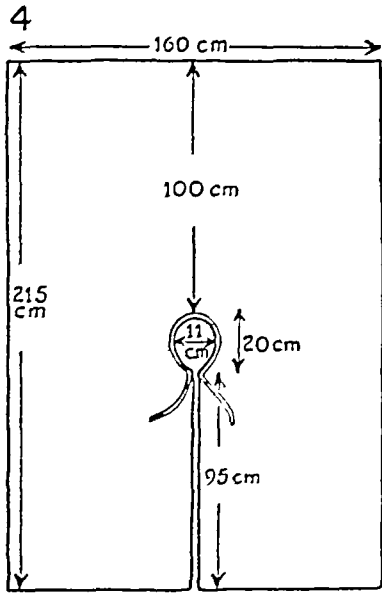
Thyroidectomy Sheet



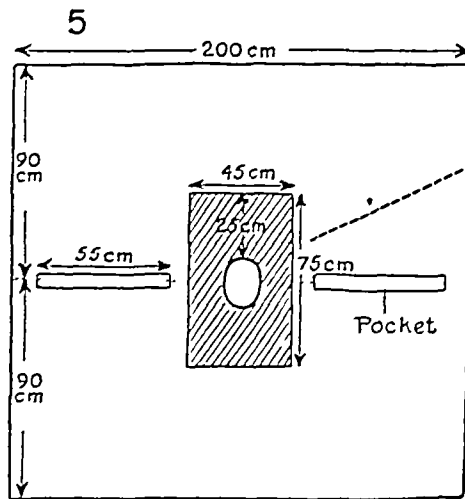
Half Sheet



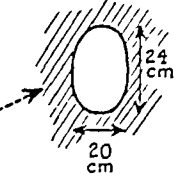
Mastectomy Sheet



Craniotomy Sheet

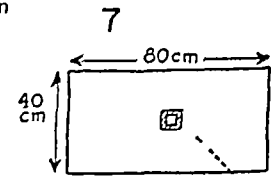


Perineal Sheet

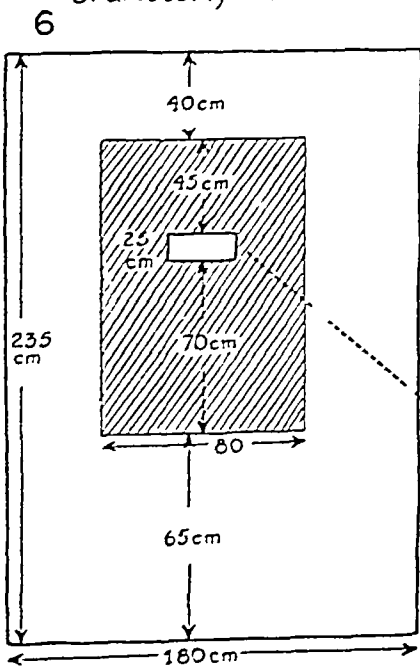
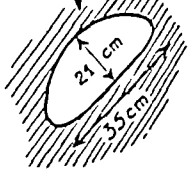


Middle seam

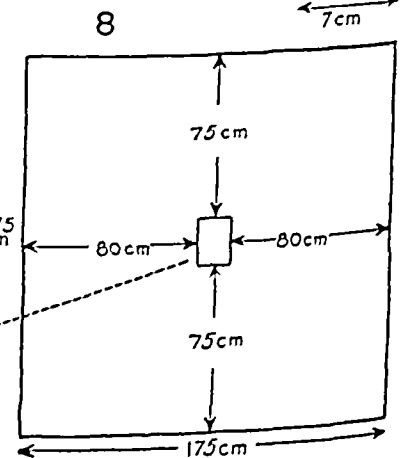
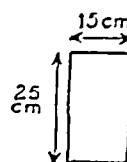
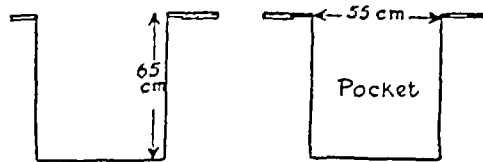
Pocket



Circumcision Sheet

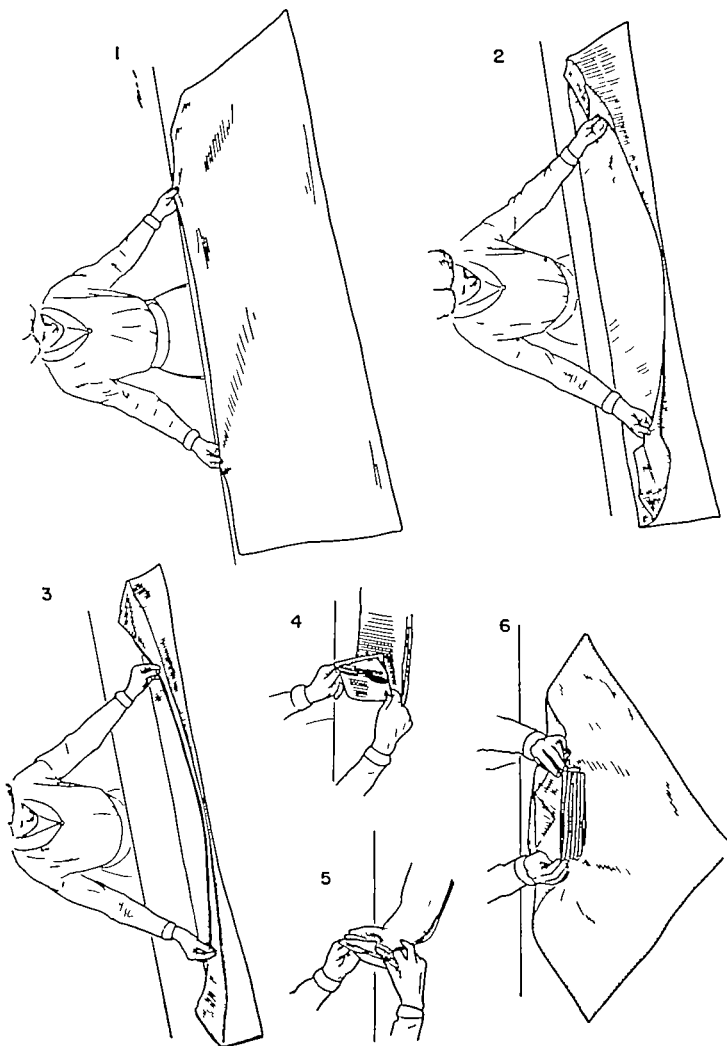


Nephrectomy Sheet

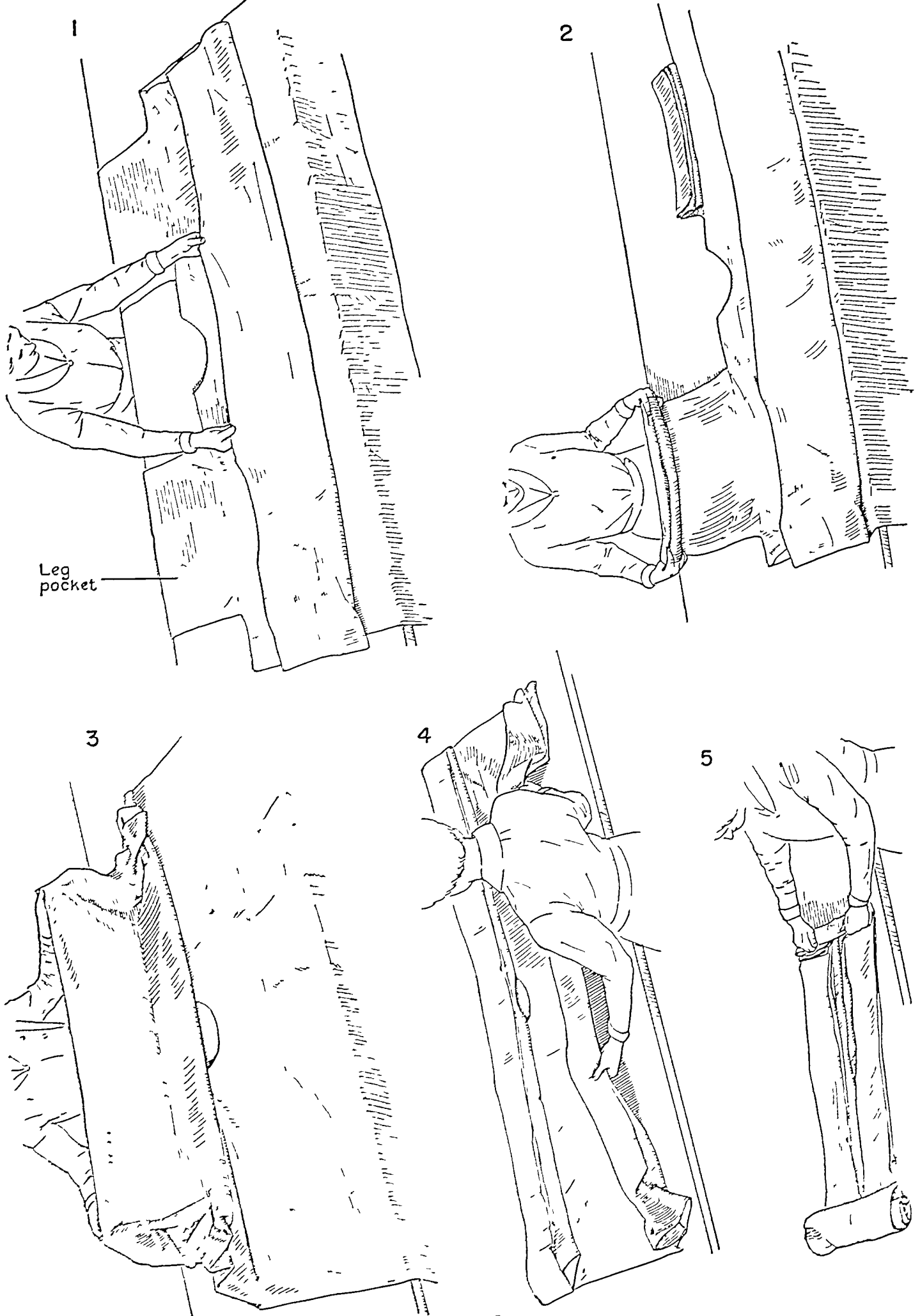


Small Laparotomy Sheet

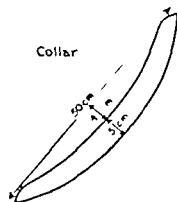
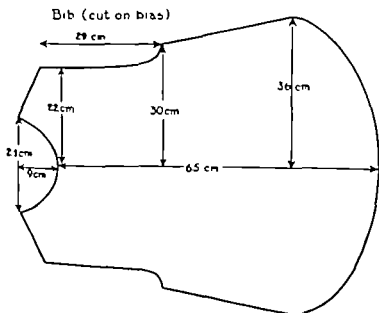
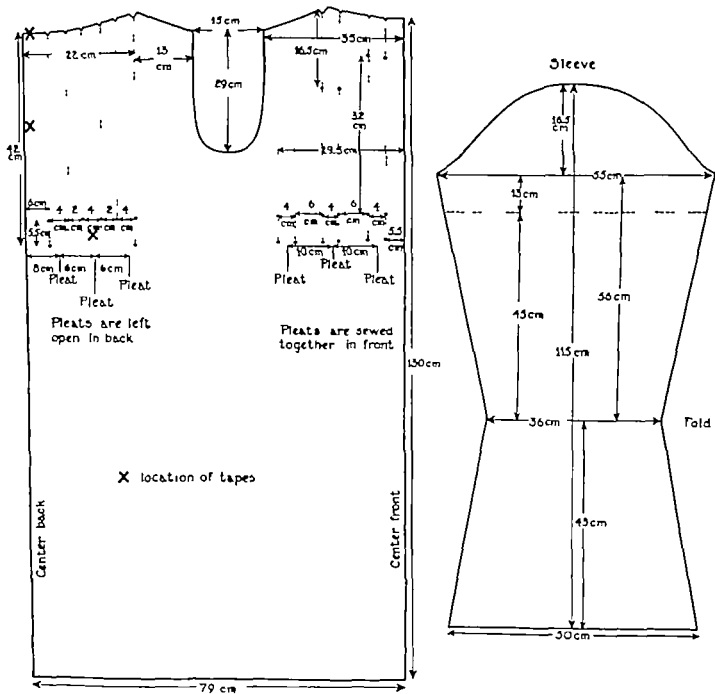
FOLDING AND PACKAGING HALF SHEET



FOLDING PERINEAL SHEET



PLAN FOR SURGICAL GOWN



FOLDING SURGICAL GOWN

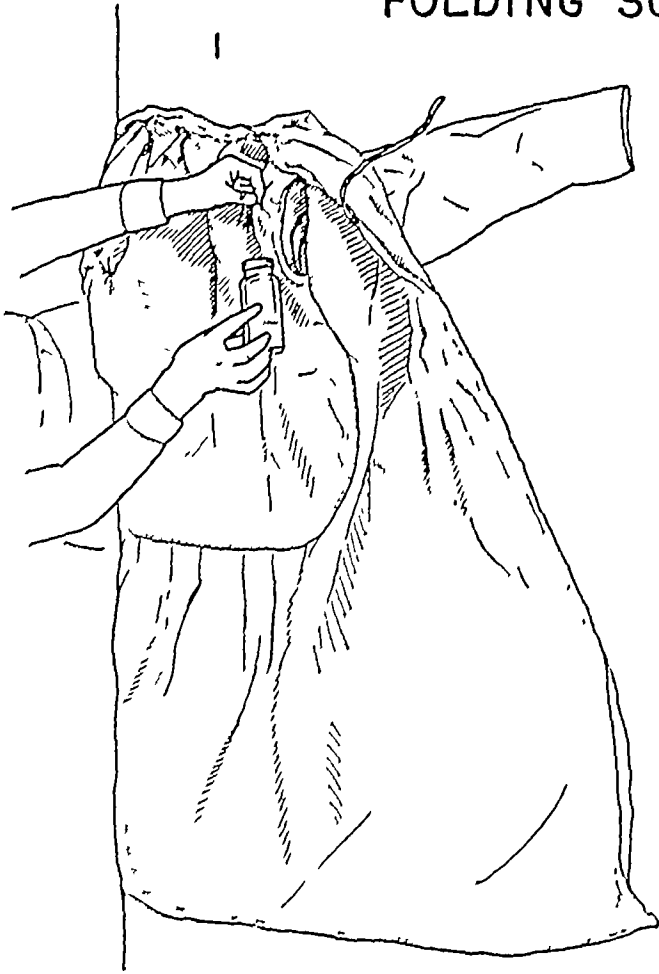


FIGURE 85

FOLDING SURGICAL GOWN

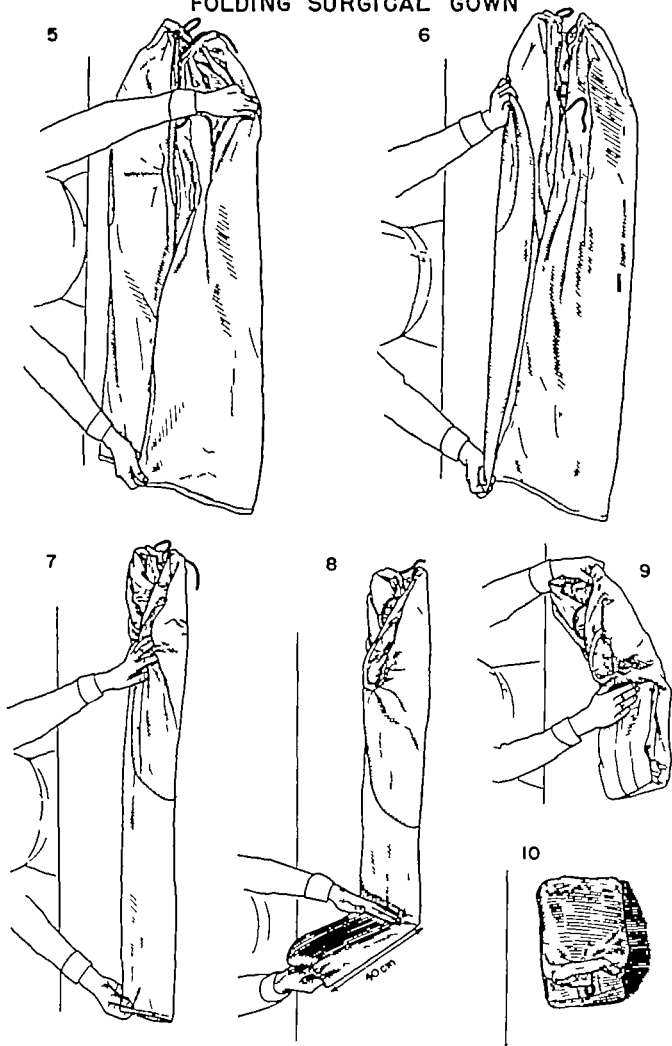
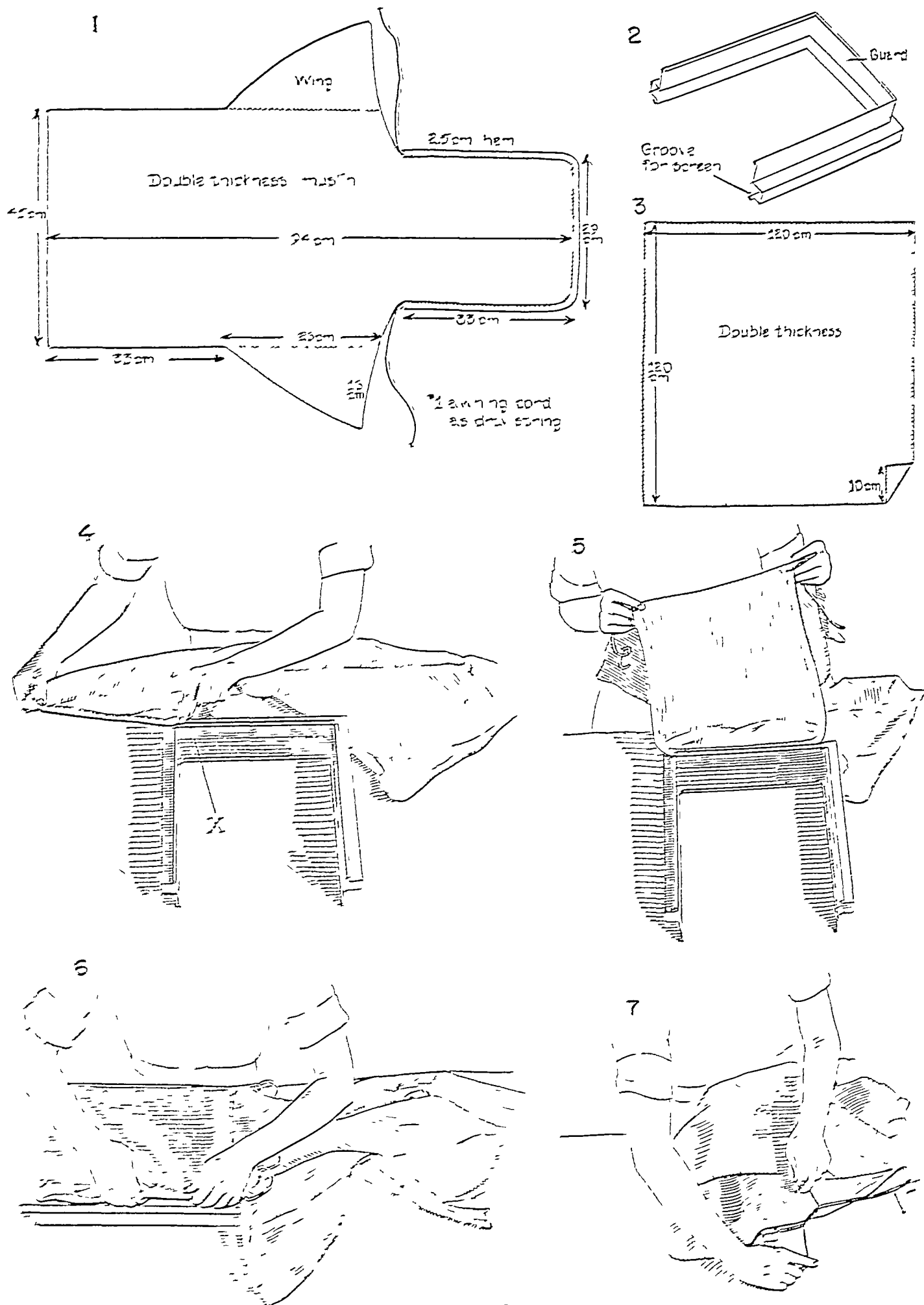


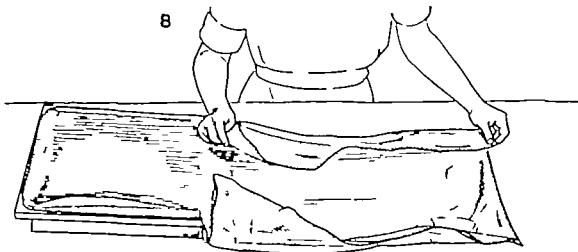
FIGURE 86

DRAPE AND GUARD FOR FLUOROSCOPE

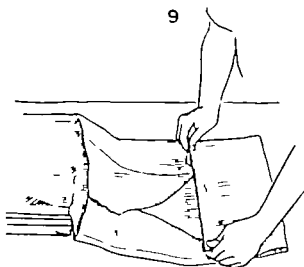


PACKAGING GUARD FOR FLUOROSCOPE

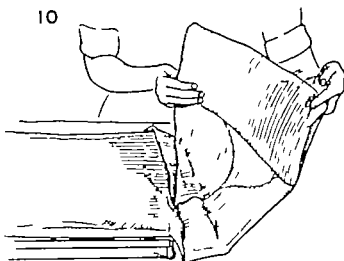
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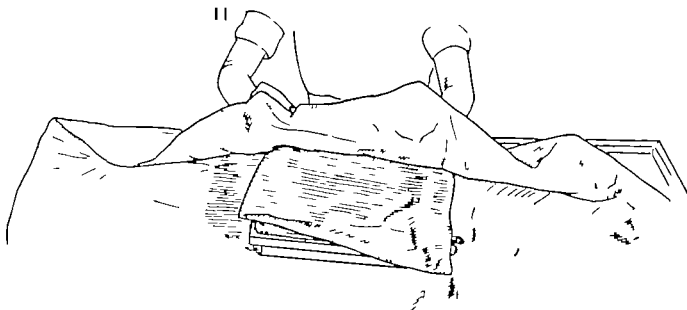
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10



11



FOLDING LONG SPONGE

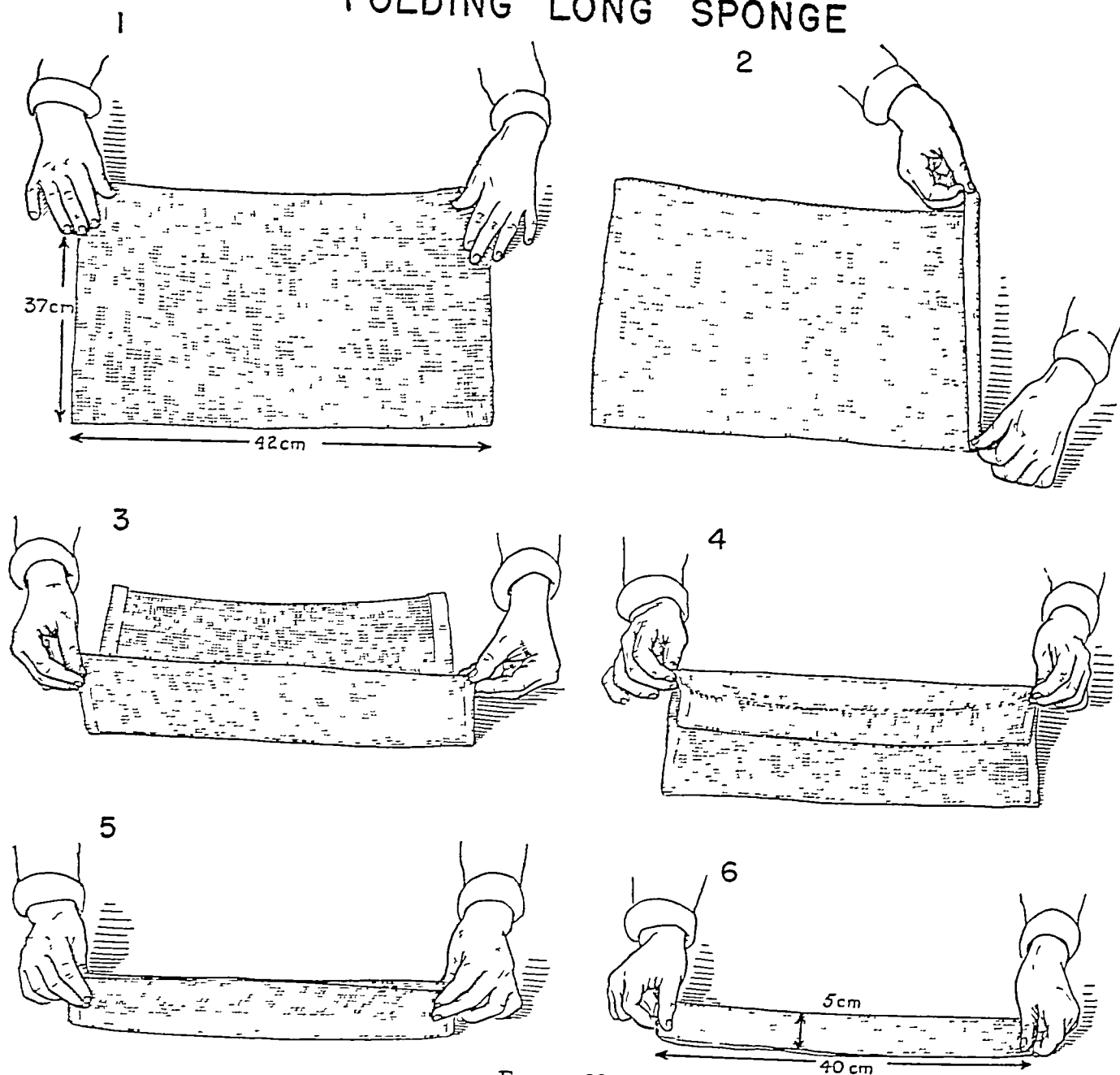


FIGURE 89

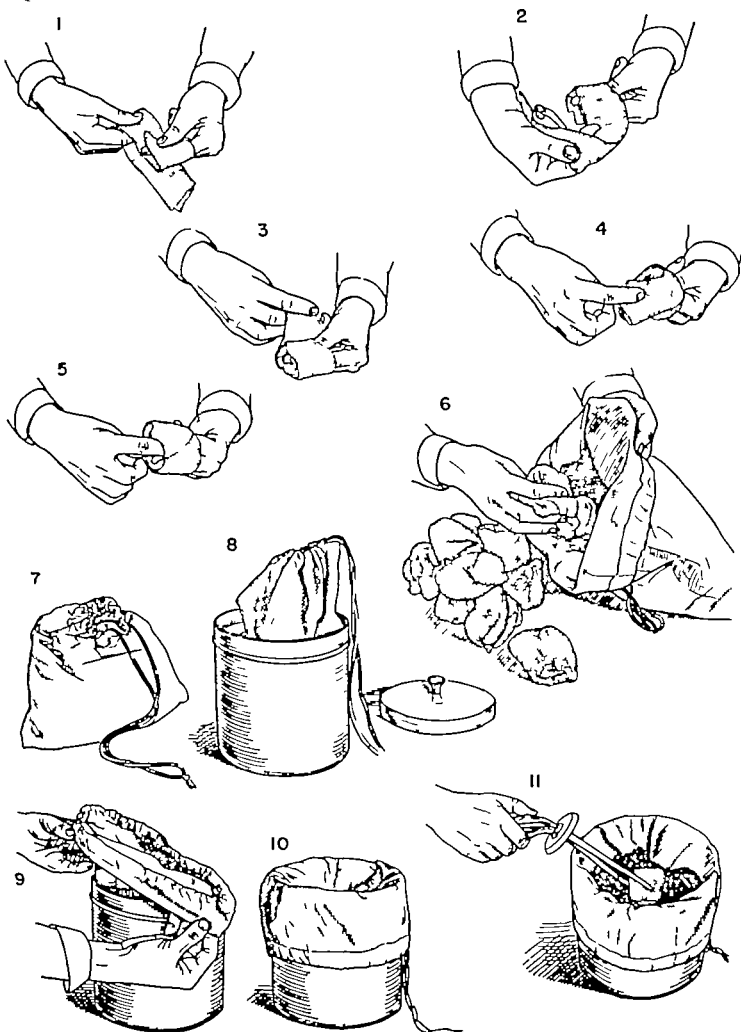
A drape for the fluoroscope is illustrated in figure 87, 1. It is designed to fit a stainless steel frame, figure 87, 2, that slides over the edges of the fluoroscopic screen to hold the drape in position and provide a guard to keep sterile fingers and instruments off the unsterile glass while the screen is manipulated in the dark.

The drawstring at *x*, figure 87, 4, is fitted into the groove at the closed end of the frame, figure 87, 4, 5, before it is forced into the groove along either side, figure 87, 6. The drawstring is pulled taut to spring the arms of the frame together slightly and is

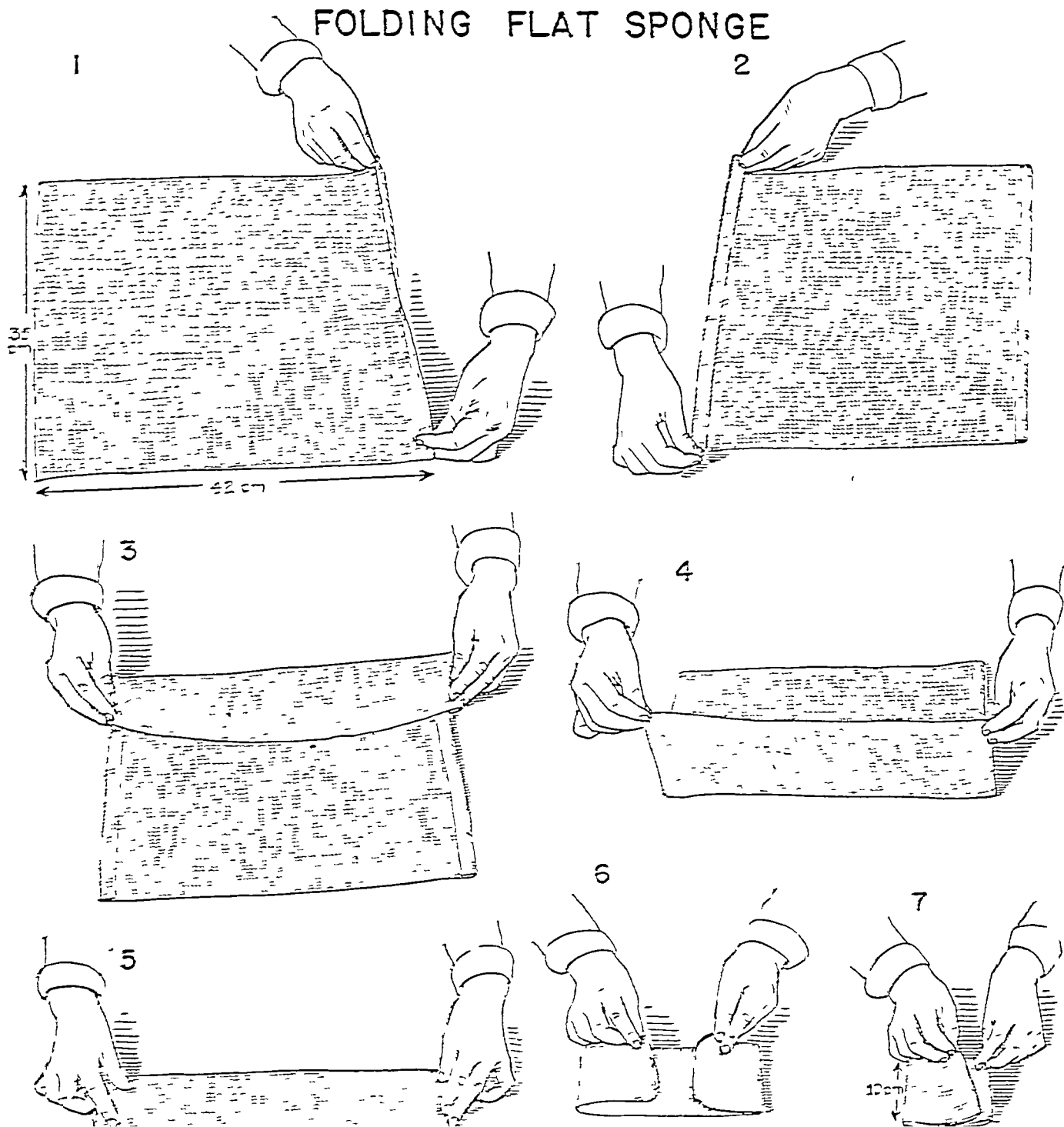
secured by a surgeon's knot, figure 87, 7. The wings of the drape are then overlapped across the center, figure 88, 8, and about one third of the tail is folded over the wings, figure 88, 9. The square formed by this fold is then turned over on top of the frame, figure 88, 10, and the assembly is packaged, figure 88, 11, for sterilization in a muslin wrapper, figure 87, 3.

The most frequently used sponge is folded from a single thickness of gauze, figure 89, 1, 37 × 42 cm. Approximately 2.5 cm of both ends are folded in, figure 89, 2, so that no loose ends present in the final

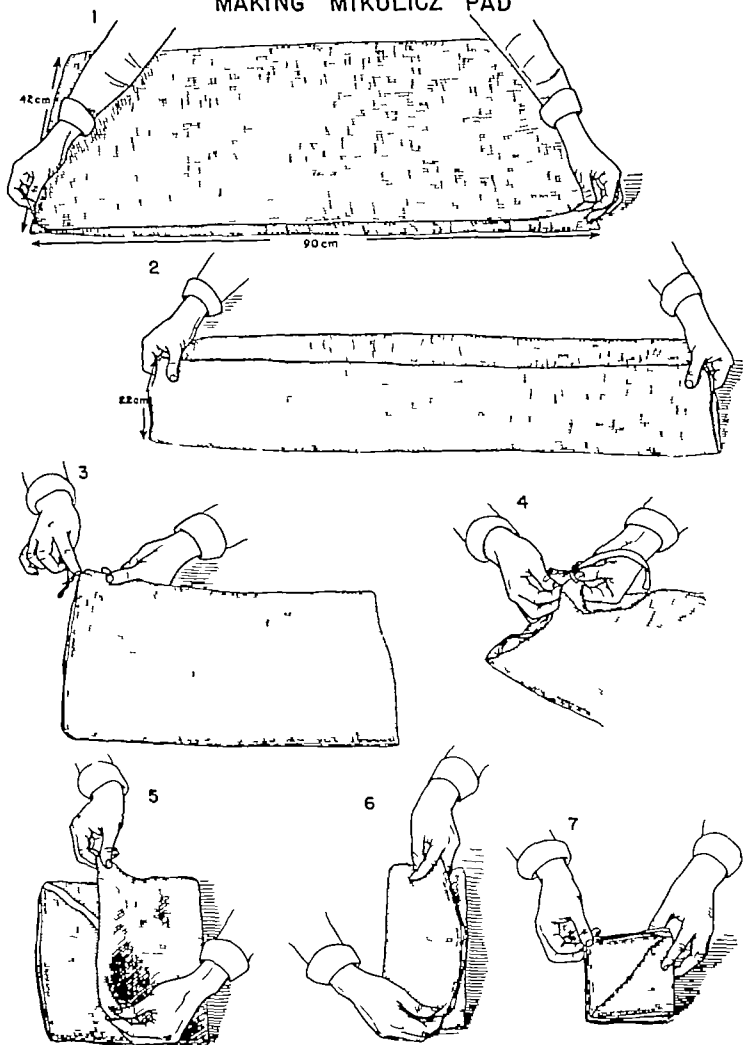
KNOTTING AND PACKAGING SPONGES



FOLDING FLAT SPONGE



MAKING MIKULICZ PAD



The 5×40 sponge may be knotted to make a firm swab for disinfecting the skin by wrapping it around two fingers and a thumb, figure 90, 1, 2, 3, and poking the outer end through the center of the roll, figure 90, 4, 5. Six of these knotted sponges are included in each kidney basin in the basin kit.

Individual sponges are reliably sterilized in a muslin bag, figure 90, 6, fitted with a drawstring, figure 90, 7. A number of these bags may be placed in a larger one and sterilized together. The sponges are readily dispensed by placing the small bag inside a can, figure 90, 8; opening the drawstring, figure 90, 9, and turning the bag down over the edge of the can, figure 90, 10, 11. The lids of these cans are sterilized in a steam sterilizer as are instruments.

Flats, small flat sponges suitable for dressings, are made exactly like those described above, figure 91, 1 to 5, except that the original gauze is but 35×42 cm in size and the final folds are transverse, figure 91, 6, so that the resulting sponge is 10 cm square, figure 91, 7. Four flats are included in each laparotomy kit for use as the final dressing.

Mikulicz pads, used chiefly for walling off the viscera in abdominal surgery, are made of gauze, 84×90 cm. in size. This gauze is doubled, figure 92, 1. It is then folded longitudinally to a width of 22 cm with the rough edges on top, figure 92, 2. The gauze is then folded transversely so that the selvedge edges approximate, figure 92, 3, and the open edges are stitched together. Some surgeons prefer to have a sheet of waterproof cellophane stitched between the layers of gauze. A loop, made of tape 50 mm wide and 7.5 cm long, is then stitched to one corner of the pad, figure 92, 4. These pads are folded into quarters for sterilization, figure 92, 5, 6, and the corner with the loop is turned back so that it

presents, figure 92, 7. Two of these pads are included in one of the small basins in the basin kit and six are placed in the bottom layer of the abdominal kit.

A uterine pack is made of a piece of gauze 15 cm wide and 6 meters long. The rough end and edges are turned in approximately 3 cm, figure 93, 1, 2, and the gauze is folded longitudinally toward the middle to make a strip 4 cm wide. This long narrow strip is gathered into 10 cm folds, figure 93, 4, 5, and inserted into a cylindrical can. One end is left protruding, figure 93, 6. The can is packaged in a muslin wrapper. At operation, the can is held above the field and the surgeon teases the strip out of the can as he packs the uterus.

For intricate dissections, a small sponge is most convenient. The "tip," figure 94, 8, is often used for this purpose. It is made of a single thickness of gauze, 22 cm square. One edge is folded in for a distance of 2 cm, figure 94, 1. 5.5 cm of the parallel edge is folded over, figure 94, 2. The gauze is folded longitudinally once more so that the 5.5 cm fold overlies the rough edge of the 2 cm fold, figure 94, 3. One end is then folded inward so that the crease makes a 60° angle with the 2 cm cuff, figure 94, 4. Enough of the opposite end is folded in at a 120° angle so that the corner of the 5 cm fold approximates the junction of the thirds of the 2 cm border. The 120° angle crease is approximated to the remainder of the 5 cm border and the protruding end is tucked into the resulting fold, figure 94, 6, 7. Fifteen tips are packaged together in a muslin wrapper.

In neurological surgery, small pledgets of absorbent cotton, known as "patties," are used. They are made at the operating table by matting fibers of absorbent cotton under saline solution, figure 95, 1, into strips of the desired width, figure 95, 2. The rough ends are grasped between the

MAKING UTERINE PACK

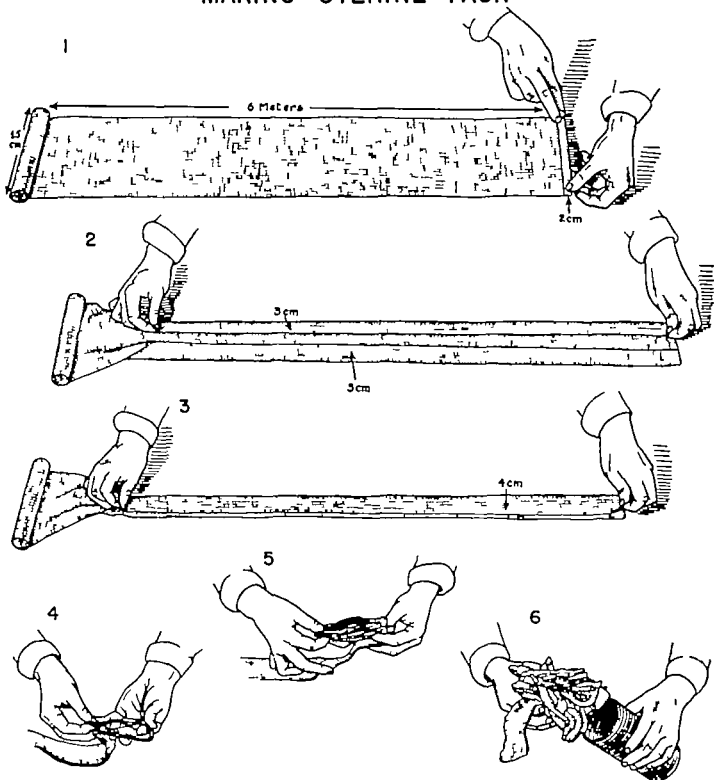


FIGURE 93

FOLDING A TIP

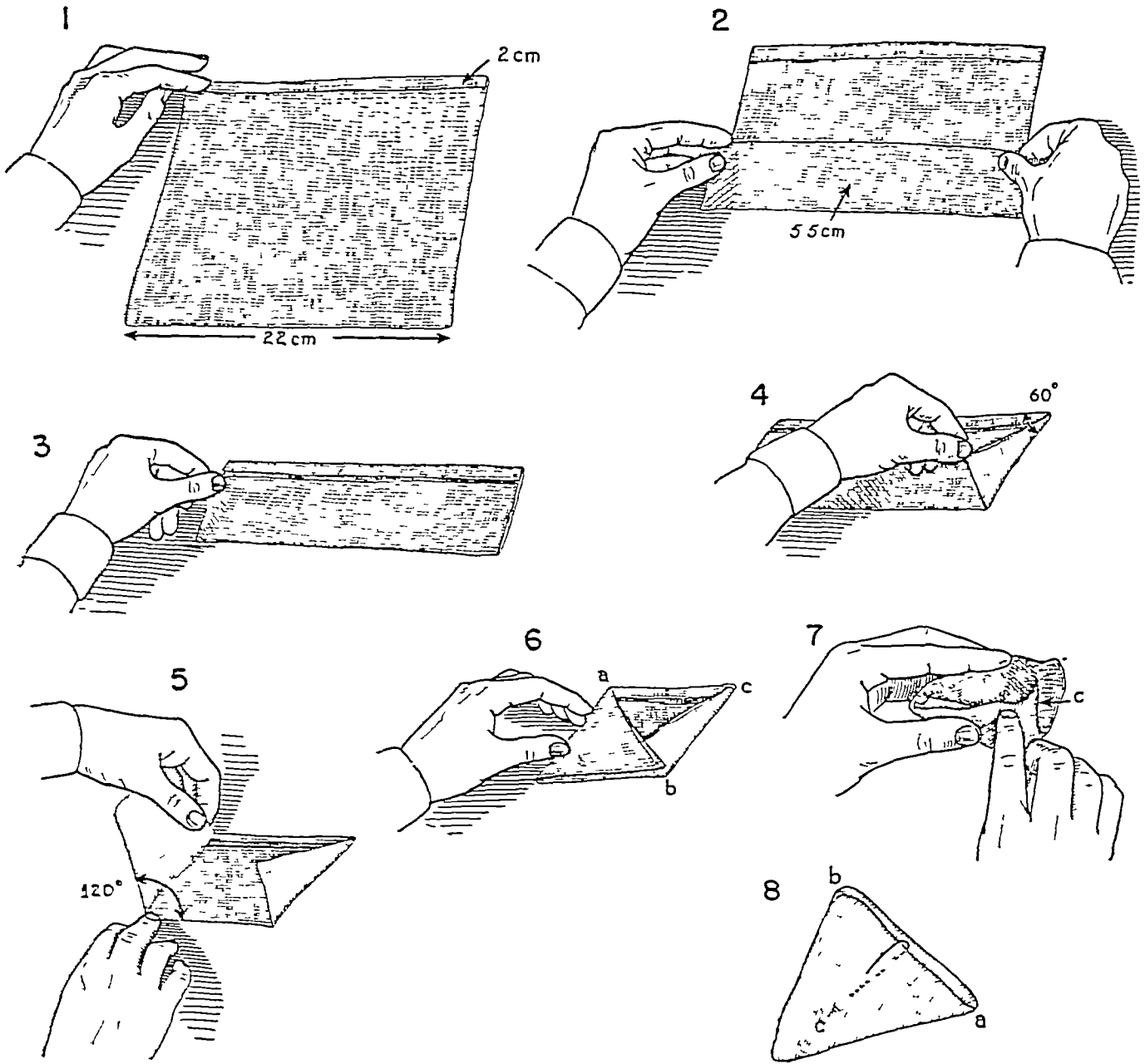


FIGURE 94

thumbs and the fingers, figure 95, 2, and the strand of fibers is turned over the thumb, figure 95, 3, and squeezed dry. The cotton strip is turned over and the ragged edge is grasped between the thumb and fingers, figure 95, 4, and the pattie is folded over the thumb, figure 95, 5, 6. The finished pattie is squeezed dry, figure 95, 7.

Birds' Eye Diapers, 45 × 91 cm, make the most satisfactory towels for draping.

They are folded in half longitudinally, figure 96, 1, then in half transversely, figure 96, 2, and again transversely in half, figure 96, 3. Six towels folded once more, figure 96, 4, are packaged in a muslin wrapper, figure 96, 5. Twelve towels folded similarly are included in each abdominal kit. For use as skin towels, it is convenient to fold the towels so that they are more accessible at operation. When

MAKING COTTON PATTIE

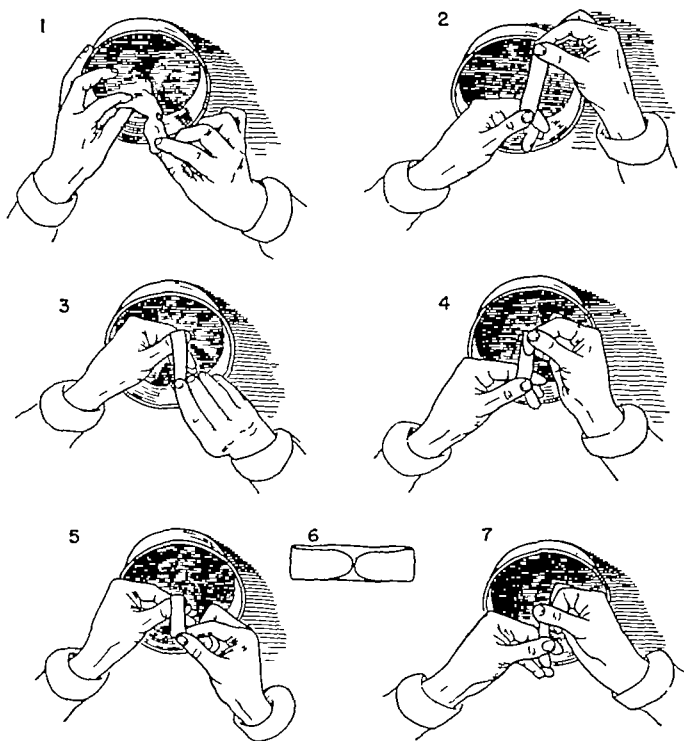
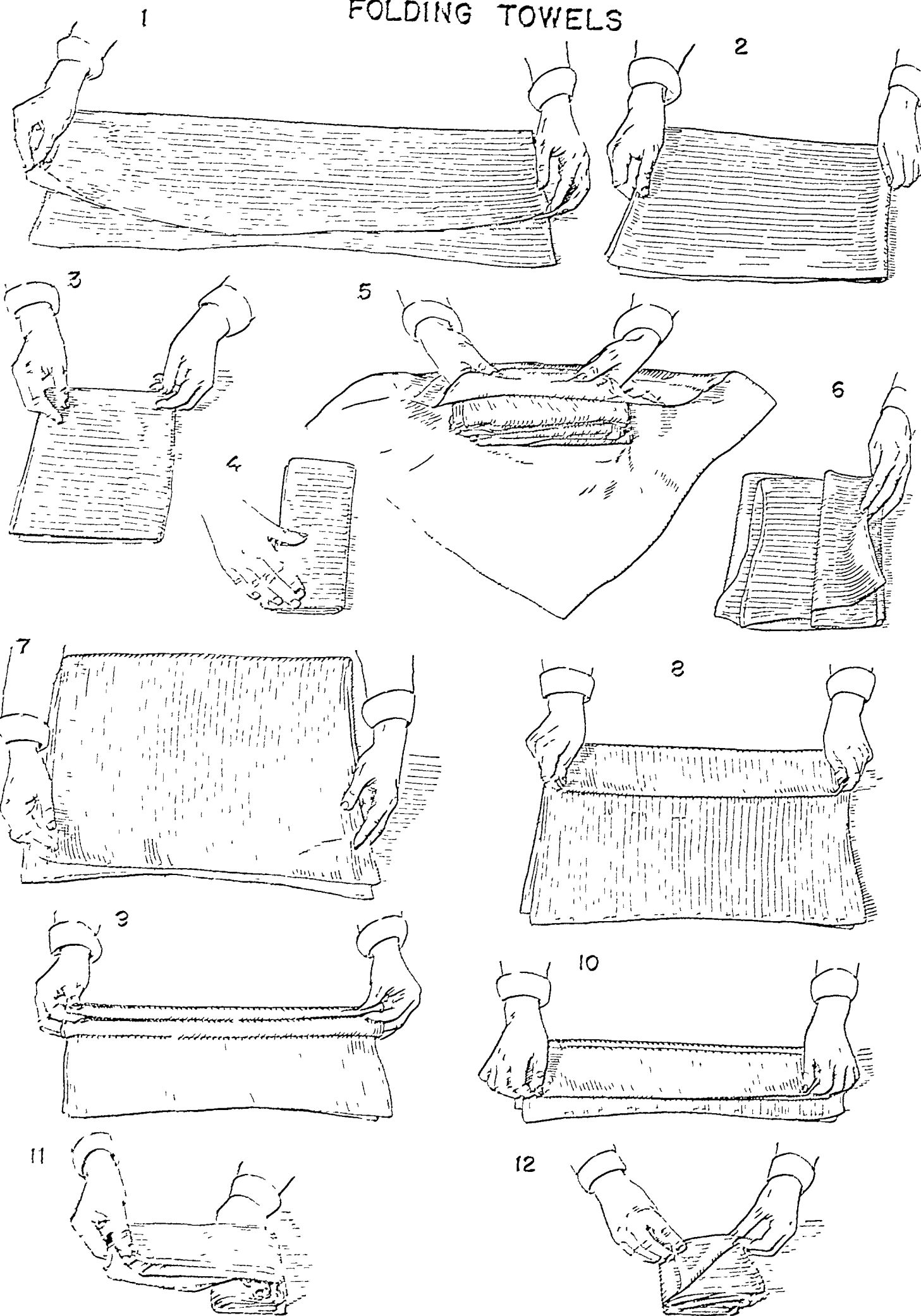


FIGURE 95

they are to be used dry, they are folded as illustrated in figure 96, 1 to 3 The top fold is then turned back as shown in figure 96, 6 Six towels folded in this manner are included in the top layer of each abdominal kit. If the skin towels are to be applied wet

they are folded in half transversely, figure 96, 7, and then pleated in quarters, figure 96, 8, 9, 10 They are then fanfolded in the opposite direction and the top two corners turned back, figure 96, 11, 12 The small size of the towel makes wringing out

FOLDING TOWELS



of excess fluid easy and the turned back corners aid in unfolding

Adequate masks can be made readily. The one in figure 97, 1, is more suitable for surgery. The strings are gathered into the hollow of the mask, figure 97, 2, and the mask is folded longitudinally in thirds, figure 97, 3, 4. It is then folded in half transversely, figure 97, 5, and six or eight masks are tied together in a bundle for sterilization, figure 97, 6. The masks are easily tied about the face. After they have been comfortably adjusted, the top edge, where it passes over the bridge of the nose, should be turned down for 6 mm. to prevent it from slipping down, figure 97, 7. If spectacles are worn, a strip of copper or aluminum may be inserted into the hem along the upper edge of the mask, figure 97, 8, and the top edge may be bent to conform to the nose, figure 97, 9, so that expired air is deflected and does not fog the lenses, figure 97, 10. The mask illustrated in figure 98, 1, finds most ready acceptance for communicable disease control,² although many like to wear it in the operating room. It is folded by approximating the corners to which the strings are attached, figure 98, 2. The resulting triangle is folded in half, figure 98, 3, and then in quarters, figure 98, 4. The strings are wrapped about the mask as shown in figure 98, 5, 6. A loop of the string near the end is tucked in, figure 98, 7, 8, 9, so that the strings can be undone readily, simply by pulling the loose ends.

The colors used in the operating room contribute greatly to the comfort and efficiency of the surgical team. Colors which absorb light and reflect little of it permit the maximum illumination of the operative field without causing constriction of the pupils and easy fatigue of the eyes. The use

of colored linen is an effectual way of enabling the surgeon to use intense illumination without causing constriction of his pupils, which would limit his vision to the central area of the retina.

The chief criterion for selecting a color, other than the correct optical property, is that the dye can be applied to cotton textiles during laundering. This technic is economically advantageous because the hospital can purchase unbleached muslin from which to make its drapes and gowns and ordinary bed sheets for sterile wrappers. The hospital laundry can dye them initially and maintain them in ideal optical condition simply by substituting a dye for the bleach usually used in the laundering process.

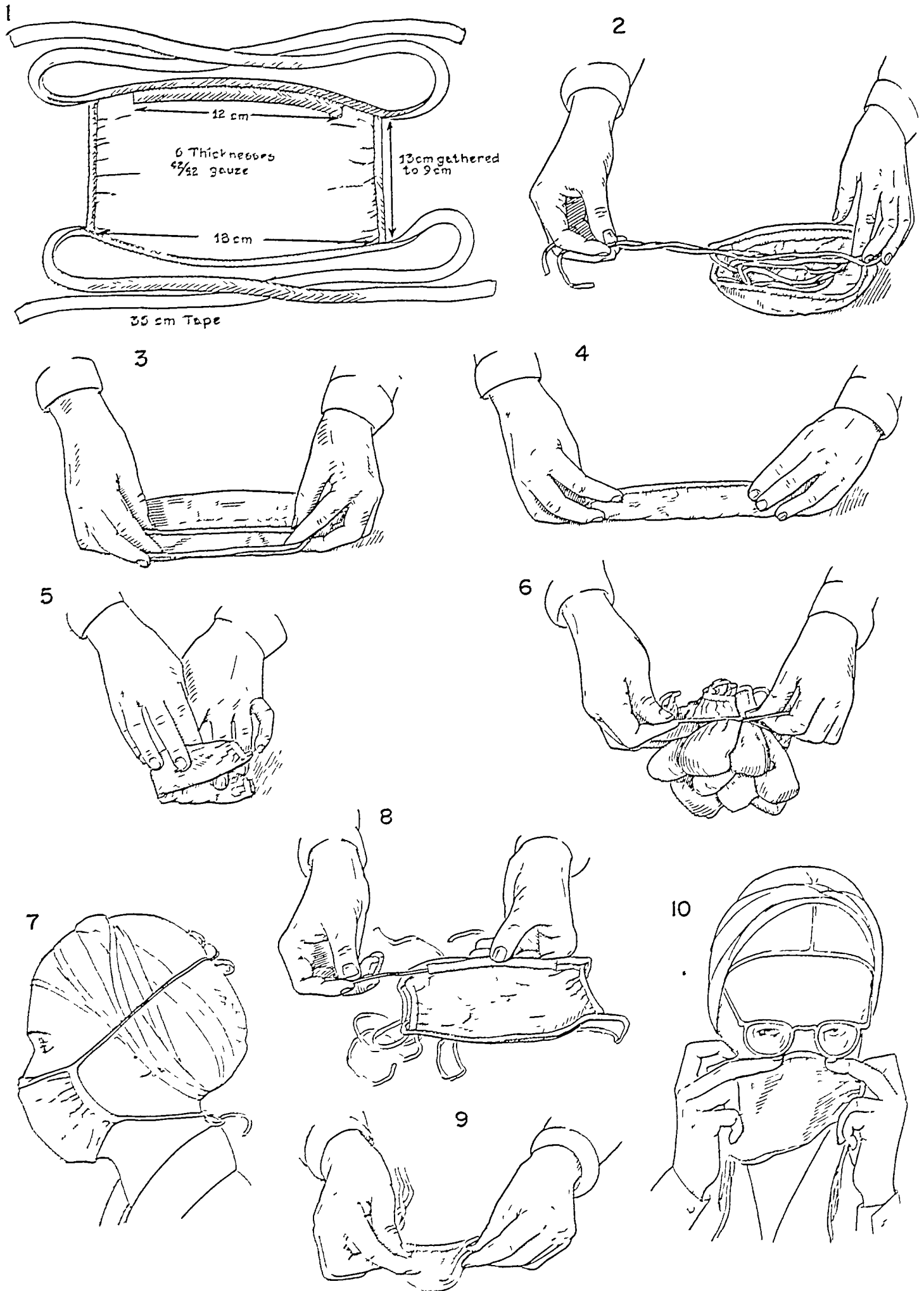
For example, after the textiles have been washed and thoroughly rinsed without souring, 20 cm. of water (200 liters) at 70°C are added to the washer. The wash water is adjusted to a pH just above seven and while the wash wheel is turning, 75 gm. of Erie Fast Grey Dye,* previously dissolved in hot water, are added for each 50 kg. of wash. The wheel is run for fifteen minutes. Then 250 gm. of common salt are added and the wheel is run for ten additional minutes. The load is then cooled, by flushing with cold water, and extracted. If the textiles are dyed every eight or ten times through the laundry, uniform color can be maintained readily. If green is preferred, 100 gm. of Erie Green, G Y concentrate, may be substituted for the Erie Grey.

Surgical supplies are usually sterilized in steam jacketed autoclaves, known as "dressing sterilizers" which differ from the simple, single-shell autoclave used in the experiment illustrated in figure 54. Dressing sterilizers are designed so that steam under

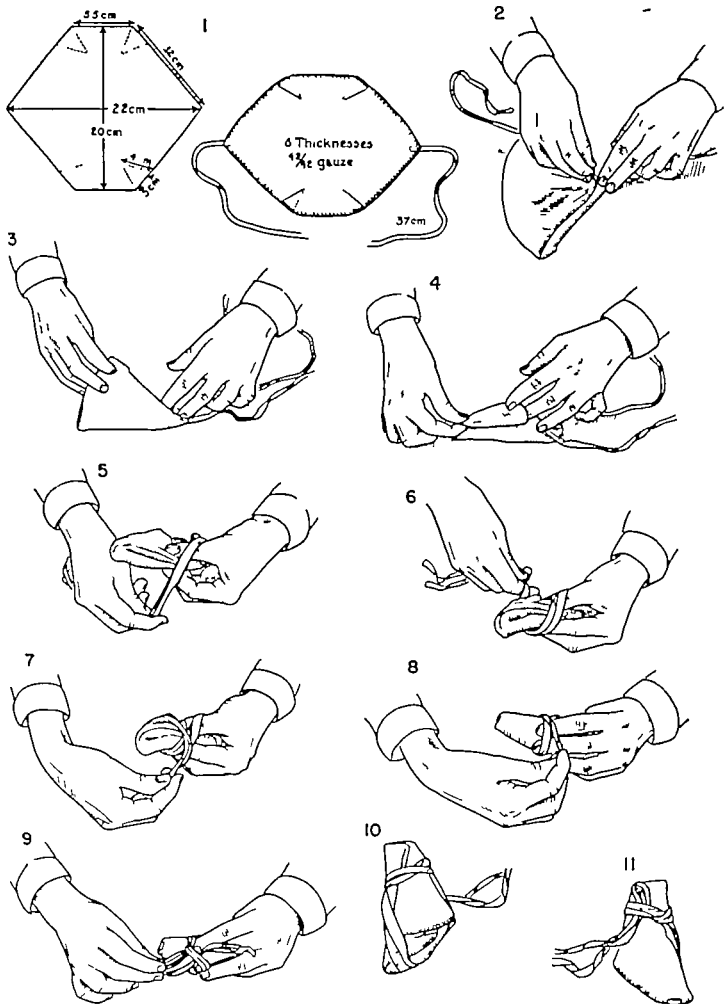
²McKITT E. H., ELLISON B. M. *Basic Principles of Aseptic Technique*. Anti-tuberculosis League of Cleveland and Cuyahoga County 1942, p. 18.

National Aniline Division, Allied Chemical & Dye Corp., 150 Causeway Street, Boston, Mass.

SURGICAL MASK



COMMUNICABLE DISEASE MASK



CUTAWAY SHOWING STEAM JACKET

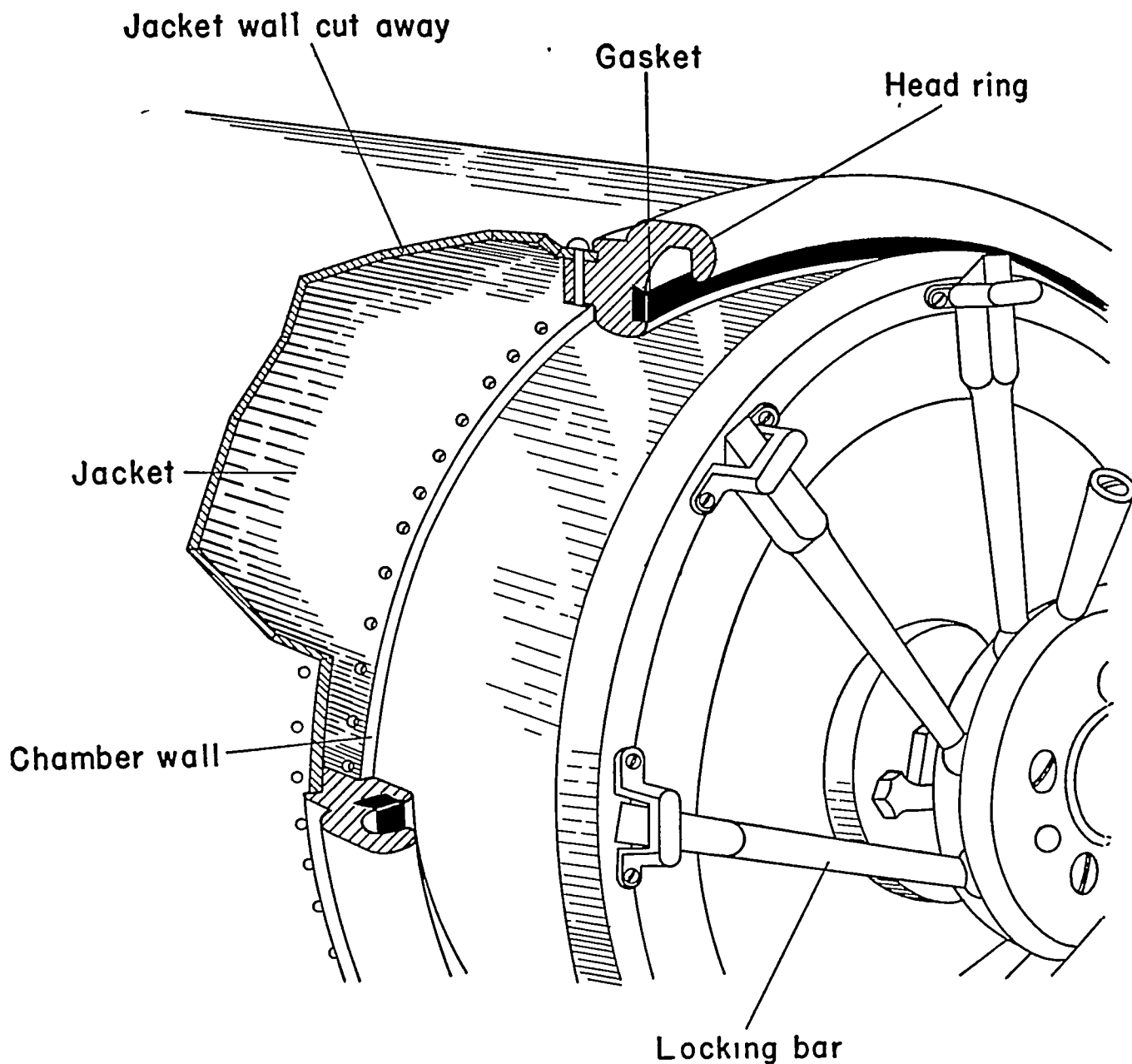


FIGURE 99

pressure can be admitted to the space between the jacket and the chamber wall to heat the latter to the temperature characteristic of the steam and thus to prevent condensation on the inner surface of the chamber, figure 99. The hot chamber wall also aids in drying the load after sterilization has been completed. Temperature studies made in such a sterilizer are mis-

leading because they may reflect the heating effect of the hot chamber wall rather than the heating efficiency of the steam within the chamber. Similarly, the fact that dressings are hot when they are removed from a dressing sterilizer does not mean that they are sterile. For example, a dressing sterilizer can be closed and steam turned into the jacket but not into the chamber which con-

verts the sterilizer into a hot-air oven. The contents of the chamber eventually are heated to the temperature of the chamber wall but that temperature is not lethal when hot air is used as the heat transfer agent. A comparable situation exists when steam is admitted into both jacket and chamber at a pressure of 775 mm. Hg gage and the air is not permitted to escape. The air and steam mixture stratifies initially but soon becomes homogeneous as it is heated by the jacket. Ultimately, it is superheated (13°C superheat, relative humidity 33%) and becomes a slow acting, unreliable bactericide

Regardless of the type of steam sterilizer used, gravity air clearance is dependable because both the air and the air and steam mixtures discussed are heavier than saturated steam under similar pressure. (Densities in kilograms per cubic meter at 121°C at atmospheric pressure, air = 0.845, steam = 0.598, under 775 mm. Hg pressure, air = 1.96, steam = 1.15)

RULES FOR THE STERILIZATION OF DRESSINGS

The essentials for the sterilization of dress

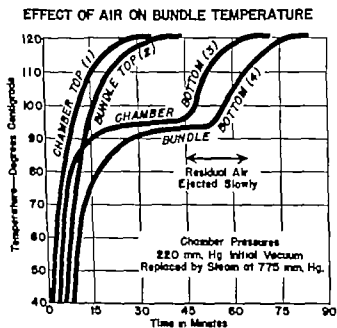


FIGURE 100

RESIDUAL AIR HINDERS STERILIZATION

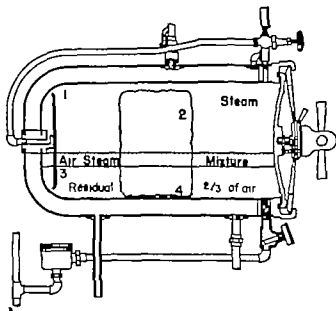


FIGURE 101

ings have already been discussed in Chapter VII. The only additional concept which must be thoroughly understood is that saturated steam must reach the least accessible spore in the depths of the bundle to insure sterility. Areas where steam does not penetrate are not moistened and simultaneously heated enough for sterilization. Contrary to popular notion, it is the lower portion of each bundle rather than its center which is the most difficult to heat in a sterilizer that is not functioning properly.

Four factors assure the development of moist heat throughout a bundle

1 Elimination of air

The clearance of air from bundles depends upon convection currents set up by the difference in density between air and steam, figure 35, and the enormous collapse in volume which occurs when steam condenses, figure 36. Figure 100 illustrates the efficacy of gravity air clearance in removing the air, not only from the chamber but also from the load. One third of the air was removed from the chamber by a 500 mm. Hg initial vacuum. Steam was then ad-

WATERTIGHT CARRIAGE PREVENTS STERILIZATION

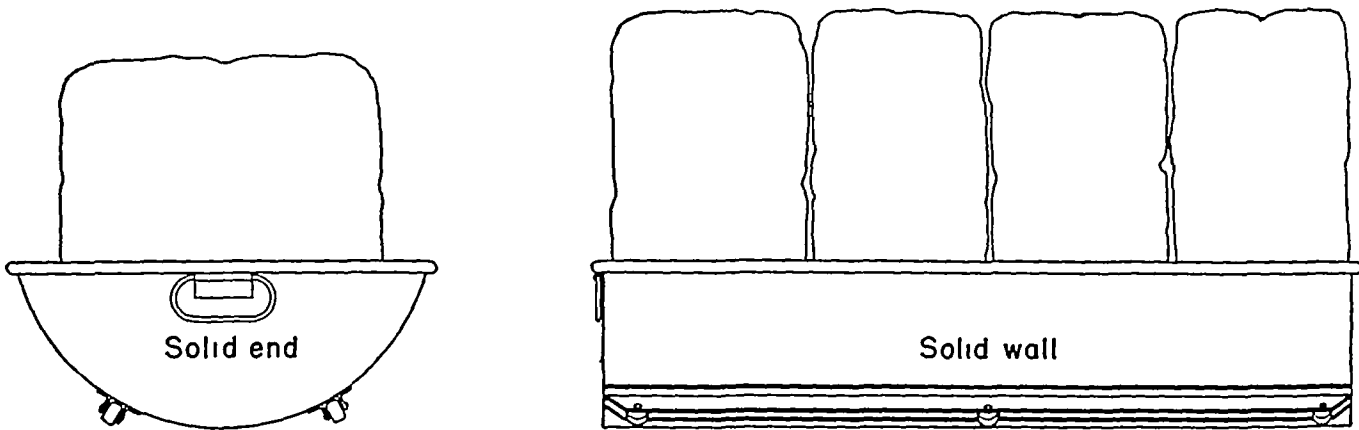


FIGURE 102

mitted under a gage pressure of 750 mm Hg. The residual two thirds of air was retained by closing the air exhaust line. The temperatures at the top of the chamber, figure 101, 7, and top of the bundle, figure 101, 2, rose as the light, hot steam stratified at the top of the chamber and compressed the residual air downward. The temperatures of the bottom of the chamber, figure 101, 3, and bottom of the bundle, figure 101, 4, remained low because the cold air that was present prevented contact with the steam.

In this experiment, spores in the top of the bundle were sterilized while those in the bottom escaped destruction because the air protected them from the steam. When the air was permitted to escape by opening the air ejector slightly, steam soon displaced the air, establishing sterilizing conditions throughout.

Despite the fact that one third of the air was removed by drawing an initial vacuum of 500 mm Hg, a widespread custom, the remaining two thirds of the air prevented sterilization until it was permitted to escape by gravity. The fallacy of the custom is obvious because gravity air clearance must be relied upon to rid the sterilizer of the residual air which interferes with steriliza-

tion. The expense of vacuum equipment and its cost of operation are needless.

An obscure way of trapping air in bundles of dry goods is to include basins or other objects which might, by chance, be positioned right side up in the sterilizer, figure 127, 8 and 9, or by attempting to sterilize bundles of dry goods in a sterilizing carriage, figure 102, in which impervious side walls and bottom prevent the escape of air.

2 *Proper wrapping in pervious wrappers*

A widespread abuse is the use of sterilizing drums. These containers invite overcrowding in that they are usually packed as are suitcases, any given number of dressings being included as long as the lid can be jammed shut. Even under ideal conditions, they interfere with the free interchange of air and steam and delay sterilization, figure 57. Packages made up of folded textile are frequently too dense for prompt penetration. The same is likely to be true of large packages where the internal arrangement is not planned to provide for easy penetration. Paper-wrapped packages do not clear air promptly because the paper is impervious, they are too difficult to sterilize in the usual dressing sterilizer to justify their use.

3 *Avoidance of superheating*

Careless operation of the sterilizer may result in superheating of the textiles, figure 43. It must be guarded against during the fall and winter months by using freshly laundered linen wherever central heating decreases the humidity of the air sufficiently to desiccate textiles.

4 *Careful loading*

It does little good to wrap packages properly if they are jammed into the sterilizer so tightly that steam cannot penetrate them. Yet, jamming is almost a universal custom and in many sterilizing rooms, the attendants use a bar to lever the door shut. In some hospitals, the sterilizer capacity is so limited that the necessary bulk of dry goods cannot be put through the sterilizer without jamming. It is stupid to expect sterile goods under such conditions. Every hospital should have sufficient sterilizer capacity so that the sterilizers are used only 85% of the time the sterilizer attendants are normally on duty.

The type of sterilizer carriage in use also influences loading. The usual basket type, figure 103, 1, invites jamming because there is always room for one more package and the weight of the load itself compresses the bottom packages and makes their penetration difficult. The ideal carriage has plane shelves, figure 103, 2, upon which articles to be sterilized can be placed. The shelves are made of expanded metal grill or wire mesh to permit free circulation of steam above and below the packages. Jamming is avoided automatically because shelves hold only so much and the excess falls off.

When these four factors are observed, the only three rules that need be enforced are:

1 *All dressings and dry goods must be sterilized before they are released for use in aseptic technique*

Lack of time is no excuse for slipping some

past or merely through an open double-ended sterilizer. In one of the largest hospitals in the country, the nurses could sterilize only one quarter of the supplies during their 7 A.M. to 7 P.M. trick. The remaining three quarters evaded sterilization and reached the operating rooms on time through the efforts of two highly praised orderlies who carried on the night shift. Six times the original sterilizer capacity had to be installed to permit nurses to sterilize conscientiously all the supplies. It is criminally false economy to permit nurses to salvage unused supplies from one operation for use in a succeeding procedure. There can be no compromise with safety!

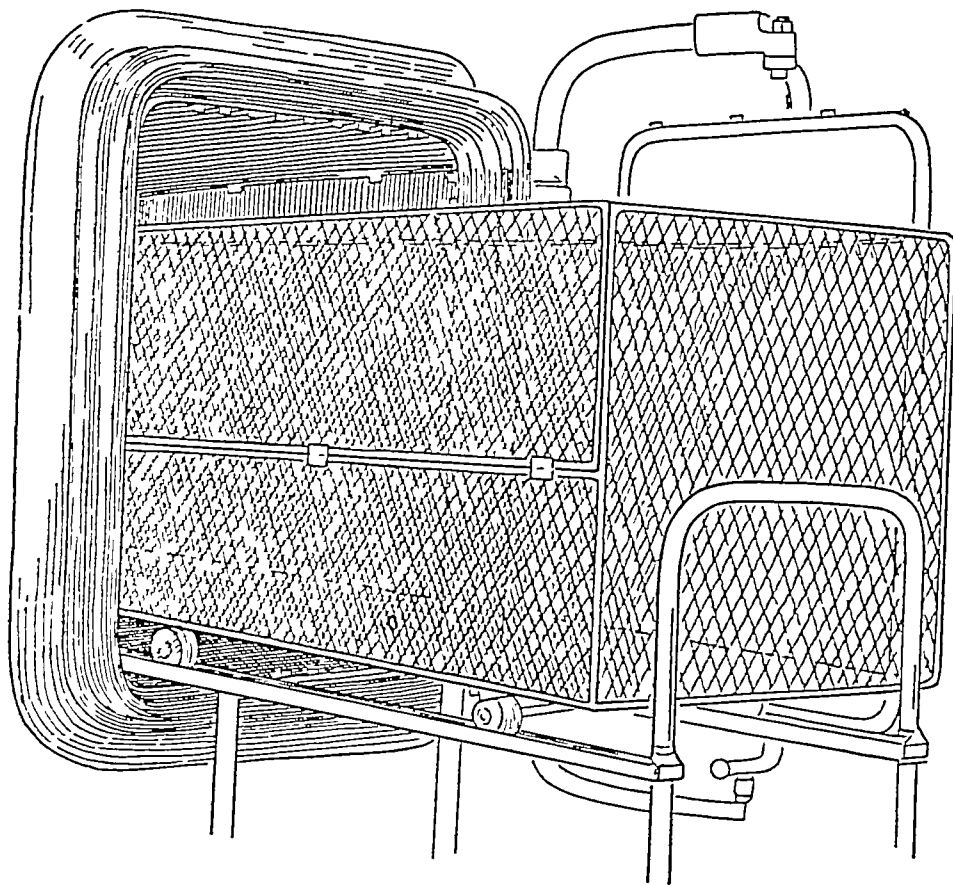
2 *All supplies must be packaged so that sterilization is certain after thirty minutes' exposure to saturated steam at 121°C*

This exposure should be made standard practice. Smaller packages are not damaged by excessive exposure. Standardization eliminates confusion and guarantees sterility of the largest bundle.

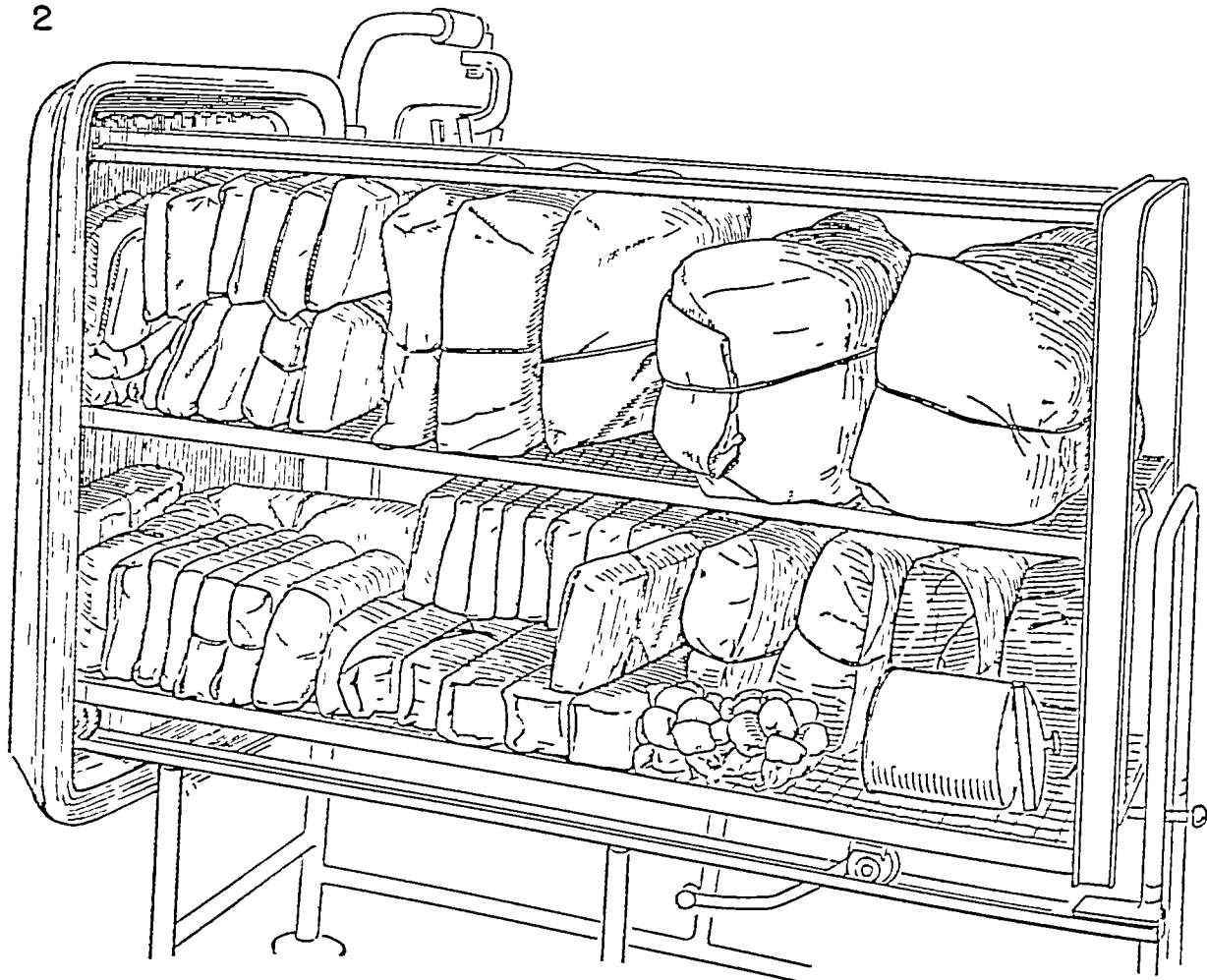
Wet dressings are usually an indication of faulty sterilization. An improper vent, figure 48, or a poorly installed steam port, figure 50, may permit condensate to drip on dressings. An air bound jacket or one full of condensate due to back pressure in the steam return, figure 53, may cause excessive condensation and moist dressings. If a sterilizer has not been leveled properly, condensate may pool at the rear of the chamber and moisten dressings in this area. This can be checked easily by pouring a glass of water into the cold chamber and noting whether it drains away promptly through the drain port. The two chief causes, however, are failure to clear all the air and tight wrapping or overloading. When air is trapped in a sterilizer, steam condenses at the steam-air interphase, figure 101, and a miniature rain storm occurs.

LOADING INFLUENCES STERILIZATION

1



2



in the stratified air. When dressings are wrapped too tightly or jammed into the sterilizer, heating by conduction occurs because steam cannot flow into the dense fabric. The energy exchange occurs at the surface of the package instead of within the depths of the bundle and condensate wets the outer layers, forming a wet shell which further hinders heating by convection.³

Jamming a sterilizer too full by closing

the door against the load will cause condensation in the textile in contact with the cold door.

3 Sterilizers must be operated conscientiously by intelligent, well trained personnel who recognize the duty as the major portion of their job rather than as an aggravating chore that prolongs their normal working hours.

³TURNER, M. *Modern Steam Sterilization, J.A.M.A.*, 60 1344-1348, 1913

CHAPTER XI

CARE AND STERILIZATION OF INSTRUMENTS

Again, if an instrument gets soiled — say, by falling on the floor during the operation — one often sees the nurse or attendant pick it up with special tongs, lift the lid of the sterilizer, dip in the instrument for a few seconds, take it out, and bring it to the surgeon as sterilized! This is not an imaginary occurrence, it happens with great frequency, and it must be carefully guarded against!

— SIR WILLIAM WATSON CHEYNE, 1925¹

THE CARE OF INSTRUMENTS

Proper care of instruments is of paramount importance for satisfactory performance and long life. Few surgical instruments wear out. The majority are destroyed by faulty cleansing and marking, improper sterilization and storage, careless handling, or by misuse. Marking an instrument on the lock, for example, figure 104, 1, may cause it to bind or may work harden the metal in the area about the imprint so that fracture subsequently occurs. The joints of delicate hemostats are cracked by careless use as pliers, figure 104, 2, light scissors are irreparably sprung when used to cut heavy bandages, figure 104, 3, the edges of periosteal elevators are dulled when pressed into service as screw drivers, figure 104, 4.

It is almost impossible to clean instruments manually. Soil that accumulates in the serrations of the jaws, the lock, and catches of the instruments hardens during sterilization and interferes with function. Some of this soil can be removed by scrubbing with soap and water but that caught in the lock cannot be removed manually. Inaccessible soil must either be leached out

by soaking in a suitable detergent or by sterilization in the instrument washer sterilizer. Instruments *must not* be cleansed with abrasive powders and soaps because they scour off the protective film and are ineffective in removing the soil from inaccessible surfaces. A cabinet of shiny instruments indicates willful destruction of surfaces which were primarily intended to resist corrosion, not to lend eye appeal.

Corrosion is the important cause of deterioration of instruments. The most destructive kind of corrosion progresses while the instruments are stored. This occurs because the locks and catches of instruments cannot be dried manually. The film of water that is left in the lock is particularly corrosive because the stud or the opposing metal surfaces in the lock are seldom finished to make them corrosion resistant. The only way instruments can be dried sufficiently to prevent this type of corrosion is by dry heat. After instruments have been cleansed and rinsed, they can be dried readily by exposure to the hot air over a steam radiator or steam sterilizer. If neither source of dry hot air is accessible, the instruments can be arranged on a tray and placed in the chamber of a dressing sterilizer. Steam is then

¹ CHEYNE, W. W. *Lister and His Achievement*. London Longmans, Green & Company, 1925, p. 119.

ABUSE OF INSTRUMENTS

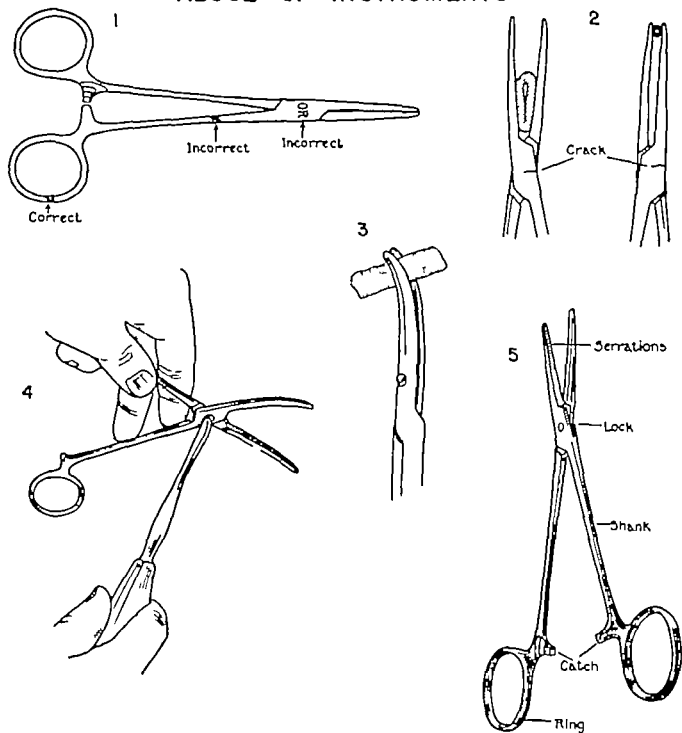


FIGURE 104

admitted to the jacket to dry the instruments promptly and thoroughly. The door must be left ajar to permit the escape of moisture-laden air from the top of the sterilizer.

Stiff instruments usually result from a structural fault in manufacture. Three fourths of new instruments are stiffer than

most surgeons like them. Number eighty emery paste applied to the contiguous surfaces of the lock and worked in by opening and closing the instrument a dozen or so times will usually relieve high spots and ease the stiffness. Old instruments stiffen chiefly because dirt and products of cor-

rosion accumulate in the lock. This dirt usually represents blood or pus which has hardened and baked on during repeated sterilization. It can be removed most satisfactorily by working a few drops of ten per cent liquid soap into the joints and then rinsing with clear water. If stiffness is due to corrosion or mechanical damage to the instrument, emery paste must be resorted to. Instruments should be handled individually or in small lots to avoid damage due to extraneous forces applied either by the sheer weight of a mass of instruments or by entanglement in a haphazard heap.

CORROSION OF METAL INSTRUMENTS

Metal instruments present problems largely because of the corrosive action of the atmosphere on instruments in storage, the damage by various chemical contacts in the operating room, and the action of moist heat used for sterilization. Corrosion can be reduced in several ways. The most widely used technic is that of protecting the steel from which an instrument is made by coating or plating it with a thin film of corrosion resistant metal.

The effectiveness of protective coats depends not upon the luster or finish of the areas where the surface is perfect but upon the unavoidable discontinuities in the protective coating.² Electroplated metals are deposited with characteristic breaks or pores at the bottom of which basic metal is exposed. The perviousness due to this cause varies with the method of plating but with any single method it tends to decrease with the thickness of the coat. Nickel plating probably forms the best protective coat but it is not pleasing because it tarnishes due to the formation of a foggy film of nickel oxide which is really the protective

film. Chromium, widely used because the chromium oxide film that forms has a bright luster and high color, and hence sells best, is in reality porous and brittle. Cadmium has a bright resistant surface which is somewhat rough. It is attacked by body fluids and may be toxic. Copper is deposited as a soft continuous surface which protects the underlying metal well but which discolors and oxidizes readily and is not pleasing. It is frequently used as a basic coating to afford maximum protection, other metals being superimposed to give the instrument sales appeal.

Other discontinuities in the protective coating are caused by cuts made through the coating by abrasion in service. The risk of this happening diminishes with the hardness of the protective metal and decreases as the coating is thickened. The protective coating of most instruments is broken by thoughtless ownership marks or trade marks which are imprinted after the coating has been applied. It is paradoxical that the proud "sold by" really means "destroyed by." Some cuts in the surface are unavoidable due to the design of locks, catches, etc., which makes it impossible to deposit a satisfactory protective coating into inaccessible crannies.

Discontinuities occur through portions of the protective coating being rubbed off by abrasion in service. Some abrasion cannot be avoided but the daily scouring of instruments amounts to willful destruction of the resistant surface. Repeated scouring often lays bare whole sections of non-resistant steel. Poor adhesion between the coating and the basic metal increases the likelihood of damage due to abrasion. This is particularly true of chromium plated instruments when an adherent undercoat has not been used.

Spontaneous peeling of the protective layer due to internal stresses is another

² EVANS, V. R. *Metallic Corrosion, Passivity and Protection*, London: Edward Arnold and Company, 1937, pp. 546-560.

cause of corrosion Platings which do not adhere well to the underlying metal, such as chromium deposited directly on steel, give rise to this difficulty

Cracking of the protective coat when the underlying metal is bent often results in corrosion. The danger of cracking increases with the thickness of the plated film and with its brittleness, hence, the practical coat is often a compromise in that a thin layer is applied to prevent cracking and peeling, whereas a thick hard coat should be applied to prevent abrasion, easy cutting in service, or to avoid pores

Sharp edges, bends, and hollows do not take sound plating because density of the electric current about such areas varies from the ideal necessary to deposit an adherent, nonporous protective coat. Because impact shatters protective coats, edges and exposed surfaces frequently break down

Modern developments in nickel plating yield surgical instruments with a relatively impervious coating which has the disadvantage of being soft (easily abraded) and fogging readily in humid atmospheres Above a critical humidity (79% relative humidity) the oxidation of sulfur dioxide, a frequent impurity in the air where coal is used as a fuel, to sulfuric acid causes a condensation of liquid which attacks the surface, forming a dull creamy film of basic nickel sulfate⁴ This action is accelerated by light.

Because of its resistance to tarnish, chromium has largely supplanted nickel as a finish for instruments This property is due to an initial susceptibility to oxidation which results in the spontaneous formation of a thin, continuous, transparent, insoluble film of oxide which renders the surface passive. Repeated destruction of the chromic oxide film by vigorous scouring causes rapid thinning of the underlying layer of chromium.⁴

⁴ VERRON W H J The "Fogging" of Nickel, *J. Inst. Met.*, 48:121 1932

Because of its resistance to tarnish, it is often erroneously assumed that chromium will prevent the erosion of underlying metals such as steel. As commonly deposited, however, electroplated coatings are somewhat porous In addition, chromium plate contains numerous fine cracks caused by the contraction which accompanies the escape of hydrogen during plating If chromium remained in its active state, it would protect the steel by sacrificial corrosion of the coating as do cadmium and zinc⁵ The formation of a passive oxide film, however, may cause accelerated corrosion of the exposed iron instead of retarding it. This type of chromium plating, often used on cheap instruments, will not withstand repeated sterilization

When a chromium surface is desired on steel as a protection against corrosion, it is common practice to deposit other metals first, such as nickel, or successive layers of copper and nickel, so that underlying pores are effectively plugged by the superimposed coatings, with a total thickness of about 0.041 mm. The final nickel surface is buffed to a high finish and a thin coating of chromium, usually about 0.0005 mm. thick, is applied The undercoatings protect against corrosion the chromium maintains the desired high luster

The chief cost in the electrodeposition of metals is the buffing and cleansing of the surface prior to plating, and polishing the coating to a high luster A recent economic development is the art of bright plating whereby electroplating is done under such carefully controlled conditions that fine crystals, shorter than the wave length of light, are deposited so that the surface is

⁴ BLUM, W and HOGANBOOM G B. *Principles of Electro-Plating* New York. McGraw-Hill Book Company 1930.

⁵ BLUM, W., BARROWS, W P and BRENNER, A. The Porosity of Electro-plated Chromium Coatings, *Bar Stand. J. Res.*, 7:697 1931

used mostly in sheet form in the manufacture of utensils. It is attacked by nitric acid, sodium hyposulfite, and sulfur-rich gas. The latter weakness has caused no end of labor in utility rooms where feces stand in contact with a Monel metal bedpan and darken it.

The stainless steels are ideal materials from which to manufacture most surgical instruments. Stainless steels are in reality steely colored metals which do not tarnish. They owe their bright finish to a surface film of chromic oxide which forms spontaneously whenever the old film is destroyed.⁹

There are many types of stainless steels, each of which is alloyed because it has specific properties which make it stainless, tarnishless, rustless, corrosion resistant to various solutions, heat resistant, etc. Each one has characteristics which influence its fabrication. Some are ductile and can be drawn; others are suitable for machining; others can be cast or forged; some weld easily, others can be hardened to hold a cutting edge. Any one instrument may be made of several types of stainless steel, each one selected by a skillful manufacturer because it contributes something to the wearing qualities or function of the instrument or because it provides for easy fabrication.

The most generally applicable steel is that commonly called "18 and 8" which was introduced in 1928. The tarnish resistance in this group is an inherent characteristic. The pollution of air with smoke, dirt, and waste gases presents corrosive conditions which few metals or alloys resist with as little change in color or loss of luster. It also resists the corrosive action of steam, water, and salt water. It is a soft non-magnetic metal which is easily worked. It can be readily fabricated into all kinds of shapes; it can be spun, welded, riveted,

and soldered, so that there is practically no limit to the designs into which it can be fabricated. It also can be cast readily in intricate shapes and is used for speculums, applicators, sounds, cabinets, operating room tables, sterilizers, and the like where temper, spring, and hardness are not important. "18 and 8" has roughly the following composition:

Carbon	0.12%	maximum
Manganese	0.30-0.60	
Phosphorus	0.03	maximum
Sulfur	0.03	maximum
Silicon	0.30-0.60	
Chromium	17.00-19.00	
Nickel	7.00-9.50	

This "18 and 8" group of steels cannot be hardened by heat treatment and higher tensile strengths are obtained only by cold-working. After annealing at high temperatures (980°-1150°C) and rapid cooling (quenching), they form a single phase austenitic solution and in this condition possess maximum softness and corrosion resistance. If this alloy is heated above 1000°C, a second or carbide phase separates and an alloy which is less resistant to corrosion is obtained. For maximum corrosion resistance, as well as to relieve severe stresses formed during fabrication which cause failure because of crystalline corrosion, the "18 and 8" alloys must be annealed carefully.

To overcome several faults of "18 and 8," various modifications have been made. The addition of silicon increases the hardness and lends desirable welding qualities to the steel as well as inhibiting the susceptibility to intergranular corrosion. Tungsten, titanium, molybdenum, and vanadium are also used to inhibit intergranular corrosion. The molybdenum enhances the general corrosion resistance against many chemicals including tissue fluids and dilute saline as well as raising the tensile strength at high

⁹ THUM, E. E. *The Book of Stainless Steels*. Cleveland: Am. Soc. Met., 1935.

temperatures. Columbium has been added, not only to retard the susceptibility to intergranular corrosion but also to prevent corrosion after reheating as occurs during welding, etc.

In the operating room, the following substances are likely to be encountered which attack instruments made of "18 and 8"

bleaching powder	oxalic acid
calcium hypochlorite	saline
ferric chloride	sodium hypochlorite (Dakin's Solution, Chlorox)
iodine	
mercuric chloride	

Other commonly used chemicals which attack the alloy are

acetic acid and salt	chlorine gas—wet or dry
acetic vapor 33% solution	chloro-sulfonic acid 10%
acetic vapor 100% solution	copper chloride
ammonium sulfate	formic acid
(plus 5% sulfuric acid)	hydrochloric acid
bromine	hydrofluoric acid
bromine water	lactic acid and salt
carbolic acid	potassium hypochlorite
carbon tetrachloride	quinine bisulfate
carbon tetrachloride	sauerkraut brine
vapors refluxed	sea water (stagnant)
chloroacetic acid	sulfuric acid dilute
	trichlorethylene 100%

Another type of stainless steel alloy, the cutlery type, contains from 12% to 15% chromium and from 0.25% to 1% carbon. These steels harden upon quenching, have a martensitic or ferritic metallurgic structure and are not suitable for drawing or forming. Careful heat treatment and polishing are necessary to develop their corrosion resisting properties. This group was among the first of stainless alloys to be popularized in 1914. It is used in two chief types, the original cutlery type which contained

provide for soundness and universality in characteristics

<i>Essential Elements</i>		<i>Associated Elements</i>	
carbon	0.7%	silicon	0.40%
chromium	16.5	manganese	0.45
		sulfur	0.03 maximum
		phosphorus	0.03 maximum

A third type of cutlery steel of inferior quality is often manufactured from raw carbon-chromium iron and is cold rolled to harden it.

It is unfortunate that the cutlery type of steel has been called "stainless steel" because corrosion resistance is not an inherent characteristic and proper heat treatment is required to bring out the maximum corrosion resistance in the higher carbon alloys.

Fabrication of the cutlery type alloys is difficult. They are susceptible to surface seams and nonmetallic inclusions. This group of steels is not suitable for cutting metals. It can be made reasonably hard but is incapable of the hardness of high carbon steels. The best knife edge is one in which hardness and resiliency are about equally proportionate. The cutting qualities of stainless steel which has been properly hardened, compare favorably with the best grades of carbon steel knives. In unsatisfactory knives, the fault is not usually in the steel but in the hardening. Cutlers who are accustomed to working carbon steel, which hardens at red heat (about 760°C) do not heat stainless steel sufficiently high (1000°C) to harden it before quenching in oil. In addition, stainless cutlery steels form temper colorings in a manner entirely different from carbon steels. These colors are therefore unreliable for judging temperatures, and salt baths or ovens must be used for drawing. During various manufacturing processes, such as forging and machining, the steel must be softened so that it can be fabricated properly. Because of sluggish

and the modified cutlery type developed to

<i>Essential Elements</i>		<i>Associated Elements</i>	
carbon	0.35%	silicon	0.20%
chromium	13.50	manganese	0.35
		sulfur	0.03 maximum
		phosphorus	0.03 maximum

molecular rearrangement during heating, heat treating operations must be carefully controlled and maintained for a considerable period of time to develop the desirable characteristics of this group of alloys. At the end of the fabrication, strains incidental to fabrication must be relieved before the steel is polished by holding it at a temperature of 705°C and allowing it to cool in air. This group of alloys is exceptionally resistant to corrosion only in the hardened condition when a clean smooth surface is exposed. Aside from proper hardening, grinding increases corrosion resistance. Stainless steel is more difficult to grind than ordinary carbon steel. It dissipates heat slowly and "grinder scorch," a yellowish-brown discoloration due to careless or unskilled grinding, occurs in local areas of frictional heat. These areas corrode readily. Wet grinding, finished by light dry grinding, is preferable. The grinding must be deep and thorough. Every trace of forge scale decarburization must be removed, since remaining oxides or pits serve as batteries and electrolytic action is set up which readily spreads over the surface of the material. For finishing, the polish must be ground on. A burnished polish leaves the surface in a distorted state favorable to staining and does not remove the scale and pits although the higher luster obtained by burnishing is deceptive. This group of stainless steels does not resist:

acetic acid vapor	citric acid
acetic anhydride	cupric chloride
acetone	dry battery mixture
alum	dye liquors (some)
aluminum sulfate	ferric chloride (as purchased)
ammonium sulfate	ferrous chloride
aqua regia	formic acid
bromine	hydrochloric acid
calcium chloride	hypo (acid)
carbon tetrachloride	iodine
chloracetic acid	lactic acid
chloric acid	mercuric chloride
chlorine	oxalic acid
chlorsulfonic acid	phosphoric acid

quinine bisulfate	sulfuric acid
quinine sulfate	sulfurous acid
sodium sulfate	tartaric acid liquor
sulfur chloride and ammonia	trichloroacetic acid

Those commonly found in the operating room are:

carbon tetrachloride	hypo (acid)
chlorine	mercuric chloride
ferric chloride	trichloroacetic acid

Many have been disappointed to find that stainless steel instruments rust or corrode almost as badly as plated instruments. Examination usually reveals that the rusting occurs at irregularly scattered points throughout the surface of the metal and that most of the objectionable discoloration is a surface film of rust which overlies a perfectly smooth, steely surface. The small spot which is the source of the film of rust represents a small bit of ordinary steel torn from the tool or die used to fabricate the instrument by the tough stainless steel which work hardens badly. This surface implant has no corrosion resistance and rusts. Careful manufacturers avoid such implants by frequent annealing to keep the steel soft, by using hard dies or nonferrous tools, or more often by removing the inclusions by a chemical treatment known as passivation. One of several methods in use is to soak the finished instrument in hot 20% nitric acid for thirty minutes to leach out the inclusion. More successful methods involve the anode treatment¹⁰ of the stainless steel which not only removes the inclusion but creates a smooth mirror-bright passive surface.

Die-cast instruments made of "white metal," a zinc alloy, or magnesium alloys will undoubtedly be seen more frequently in postwar instruments. White metal is not as suitable as the magnesium alloys because it gradually crumbles under repeated steri-

¹⁰ LIPPERT, T. W. Electropolishing — A Symposium on Today's Practice, *The Iron Age*, December 26, 1940

lization Magnesium or its alloys should not be implanted in tissue because they prompt a destructive foreign body reaction.¹¹

Vitallium is a recently introduced alloy of 65% cobalt, 5% molybdenum, and 30% chromium. It is a bright alloy which has no electric potential in tissues and is therefore inert,¹² its great fault being that it cannot be machined and must be cast and ground to shape. Casting defects occur frequently which interfere greatly with its strength and make it a disappointing metal to use.

Ticonium is another corrosion resisting alloy that is well tolerated when implanted in tissue.¹³ It is composed of nickel, cobalt, chromium, and molybdenum.

Tantalum, one of the acid resisting elements, is inert in animal tissues. Because it is malleable and ductile, it is useful in alloplastic technic.¹⁴

A less satisfactory but helpful technic for avoiding corrosion is the modification of the sterilizing cycle to prevent as much corrosion as possible. The use of 0.5% to 2% sodium carbonate or 0.05% to 0.1% sodium hydroxide as the sterilizing fluid in non-pressure sterilizers inhibits corrosion. The simple expedient of bringing the water to the boiling point before immersing instruments is also effective because the oxygen is driven out of solution and is no longer present to cause corrosion. In a steam sterilizer, excessive condensation on cold instruments can be avoided by preheating the instruments in a sterilizing chamber

with the door closed and steam pressure in the jacket. In this way, an infinitesimal film of moisture forms during sterilization and rapidly evaporates when the steam pressure is relieved. Incomplete air clearance from a steam sterilizer causes corrosion because the precipitation which occurs at the air steam interface dissolves oxygen out of the air and accordingly has more electrolytic action than saturated steam.

RECOMMENDED TECHNIQUES FOR THE STERILIZATION OF INSTRUMENTS

There are several acceptable techniques for the sterilization of instruments. They will be discussed in the order of preference, first choice being those which are foolproof and bacteriologically safest.

The problem in the sterilization of instruments is the rapid destruction of spores, many of which are resistant to both physical and chemical agents, particularly when protected by a film of oil or a coating of protein. To be reliable under all conditions, this procedure must be so rapid that attendants are not tempted to improvise shortcuts. Inconvenience, face saving, and impatience militate against any technic which requires more than ten minutes for completion. Even that period is too long for emergency sterilization. Instruments cannot be sterilized reliably unless they are open so that there are no tightly apposed surfaces to protect bacteria against contact with moisture.

Many ignore sporeformers in the belief that they are uncommon in the operating room. However, such organisms have been demonstrated postoperatively on 12% of the cutting instruments used in clean operations and on 8.5% of the knife blades used for skin incisions.¹⁵ The dust from operating

¹¹ SCHULZ, R. Z. and WALTER, C. W. Magnetoallogenic Pneumogramuloma, *J. Indus. Hyg. & Technol.*, 24: 148-152, 1942.

¹² VERABLE, C. S., STUCK, W. G. and BEACH, A. The Effects on Bone of the Presence of Metals Based upon Electrolysis, *Ann. Surg.*, 105: 917, 1937.

¹³ CAMPBELL, E., METZOWSKY, A. and HYDE, G. Studies on Use of Metals in Surgery: Comparative Determinations of Cytotoxicity of Certain Metals in Fibroblast Culture, *Ann. Surg.*, 114: 472-479, 1941.

¹⁴ PUDENZ, R. H. The Use of Tantalum Clips for Hemostasis in Neurosurgery, *Surgery*, 12: 791-797, 1942.

¹⁵ ROBERTS, K., JORDON, W. W. and BRUCKNER, H. S. Aseptic Peritoneal Cavity — a Misnomer, *Surg., Gyn. & Obs.*, 57: 752, 1933.

room floors and shelves yields cultures of resistant, sporebearing bacteria. Ineffectual terminal disinfection of instruments soiled with oil, feces, septic blood, or pus is a prolific source of such contamination.

PREOPERATIVE STERILIZATION

The action of the instrument washer sterilizer, figure 109, is so rapid and satisfactory that it can be used advantageously for the preoperative sterilization of instruments. It affords a convenient means for absolute sterilization.

Lacking the above equipment, the most desirable technic for the sterilization of instruments is the use of saturated steam either at 132°C or 121°C, the only advantage of the former being speed. The instruments can be arranged on trays or wrapped in muslin wrappers and should be subjected to saturated steam at 121°C for a minimum of fifteen minutes. If they are to be stored following sterilization or if corrosion causes difficulty, much of the wetness can be avoided by preheating the load of instruments for fifteen minutes before turning the steam into the chamber. In this way, the instruments are heated by radiant energy to 121°C and condensation is minimized.

A satisfactory but time-consuming technic is the use of dry heat. The most applicable method is that of putting the instruments in the chamber of a dressing sterilizer and closing the door. Steam is then turned into the jacket but not the chamber and the instruments are exposed to the dry heat for a minimum period of four hours, or more conveniently, overnight.

Nonpressure sterilizers, using boiling water as the bactericide, are most frequently used for the sterilization of instruments. They are adequate for a technic of sanitation rather than sterilization but whenever sporebearers are unwittingly encountered,

disaster is inevitable. Certain precautions can be taken to increase their efficiency. Everything must be submerged and wet by the water. Oil and grease must be kept out of such sterilizers and alkali can be added to make the water a more efficient bactericide. The sterilizing period should not be timed until actual boiling occurs. The safe minimum is thirty minutes' boiling unless alkali has been added to the water, then a fifteen-minute period suffices.

The chemical disinfection of instruments is discussed in Chapter IV.

THE EMERGENCY STERILIZATION OF INSTRUMENTS

Even in operating rooms where instrument kits are adequately sterilized prior to operation, there are opportunities for unsterile instruments to reach the operative field. These breaks in aseptic technic are countenanced by surgeons because there have been no quick, reliable methods for the emergency sterilization of instruments or the postoperative sterilization of instruments contaminated with virulent bacteria or spores. The need for emergency sterilization arises daily. The exasperating delay which follows discovery of the omission of an instrument from the kit, the accidental contamination of a special instrument, or the request for instruments required by an unexpected change in operative procedure is familiar in most operating rooms. In many clinics, quick sterilization, boiling for one or two minutes in a small electric sterilizer or chemical disinfection, wiping the instrument with a germicide, are sanctioned because of the emergency. In operating rooms where more thorough emergency methods are used, the impatient surgeon may stampede a timid circulating nurse into returning an instrument to the operative field before it has been adequately sterilized.

Instruments can be sterilized quickly and

efficiently for such emergencies in a specially constructed pressure sterilizer equipped with accessories which permit the completion of a sterilizing cycle in less than four minutes.¹⁴ This striking decrease in the cycle is possible for two reasons. Almost all modern surgical instruments present nonporous surfaces and sterilization is strictly a surface phenomenon where time for penetration by steam can be omitted safely. Because the thermal death time of bacteria decreases exponentially with increase in temperature, a lethal period, short enough to permit true emergency sterilization, is quite practical when the temperature of the steam is raised to 132°C.

Before placing instruments in such a sterilizer, dirt and grease must be removed by scrubbing with soap and water and slushing in a fat solvent. "Stod Sol" is a safe, efficient solvent. The clean oil free instruments are opened and placed in the sterilizer on a perforated metal tray and the door is closed tightly. Steam is then admitted to the chamber so rapidly that a sterilizing temperature of 132°C is attained in forty seconds, figure 107. Spores of the most heat resistant organisms are destroyed at 132°C in two minutes. An automatic, recycling timer meters a consecutive sterilizing interval of three minutes and signals that the load is sterile and that the steam may be vented. Pressure in the chamber can be relieved almost instantly. A detachable handle is then fitted to the sterilizing tray and the instruments can be carried to the operative field without danger of dropping or contaminating them, figure 108. This technic enables the circulating nurse to provide the surgeon with sterile instruments in less than five minutes after their need becomes apparent. Because of the rapid action and high temperature attained in this sterilizer, spotting and corrosion of instruments are eliminated.

PROCESS CHART--EMERGENCY STERILIZER

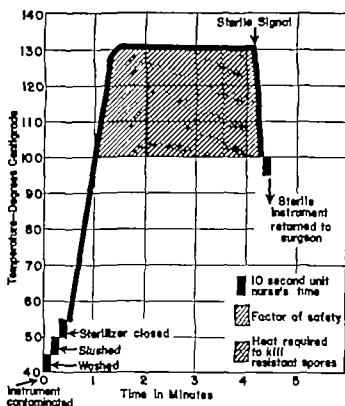


FIGURE 107

Walter¹⁴

Emergency sterilization can also be done easily in the instrument washer sterilizer by putting just enough water into the sterilizer to cover the instruments. The water is quickly heated to 132°C, the air is purged from the sterilizer, after two minutes at 1400 mm. Hg gage pressure, the pressure can be relieved and the instruments are ready for immediate use. This technic is justified only if care is taken to clean the instruments thoroughly to remove all oil and grease before putting them in the sterilizer.

TERMINAL STERILIZATION OF INSTRUMENTS

A safe, rapid technic for the cleansing and sterilization of instruments consists of exposing them to superheated water in a sterilizer designed to remove the oil and

¹⁴ WALTER, C. W. Technic for the Rapid and Absolute Sterilization of Instruments, *Surg., Gyn. & Ob.*, 67:244-248, 1938. By permission of *Surgery Gynecology & Obstetrics*.

TRAY FOR EMERGENCY STERILIZER

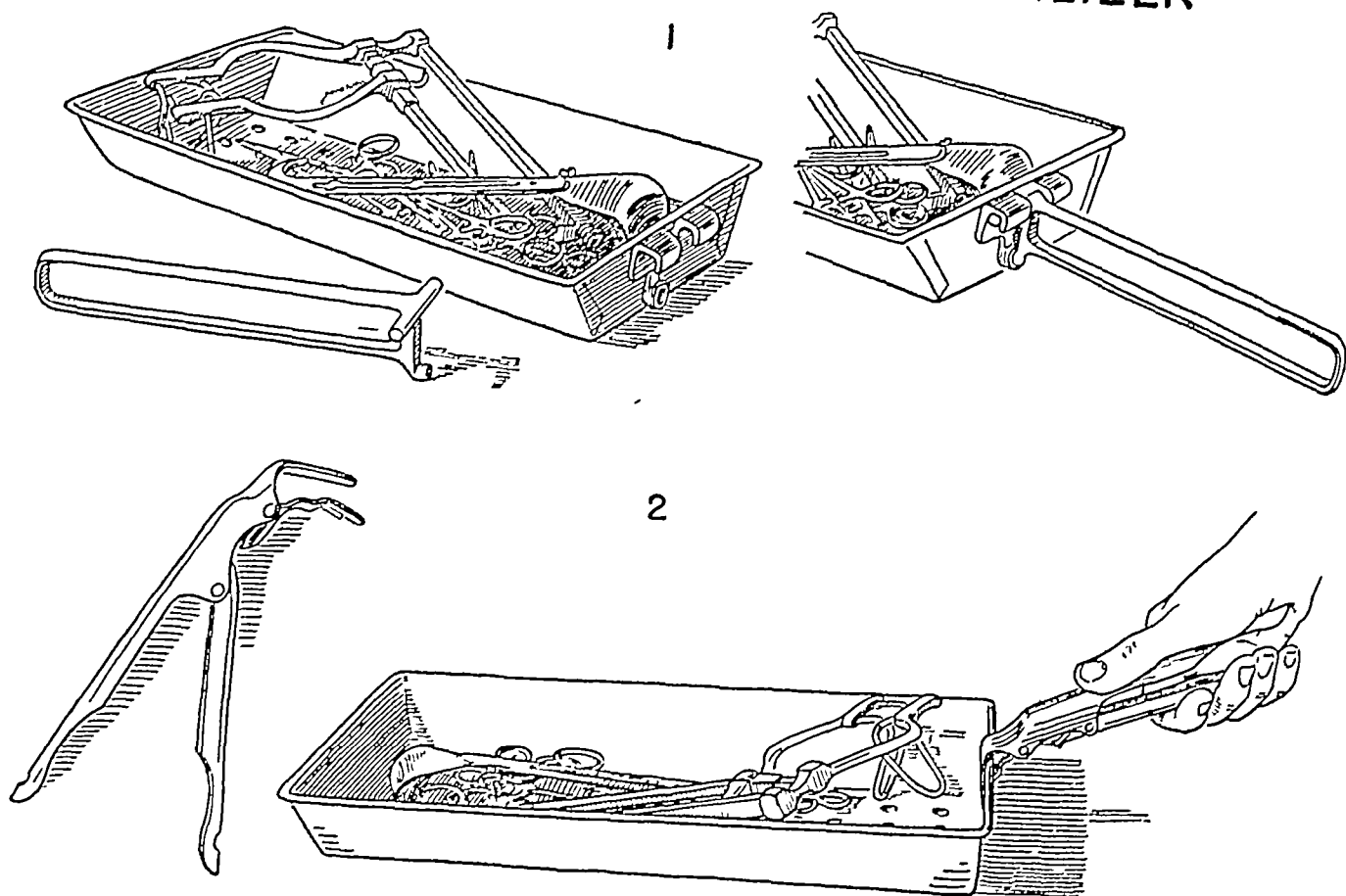


FIGURE 108

scum from the surface of the water, leaving a monomolecular film of oil ¹⁷ which can be sterilized. The dirty instruments are collected in a stainless steel bucket directly from the instrument table by the scrub nurse responsible for the case, the only preliminary treatment being that of releasing the catches so that all surfaces are exposed. The bucket is placed in the sterilizer over a baffle which forces water to circulate through perforations in the bottom of the bucket, figure 109. A steam coil, located beneath the baffle, supplies adequate heat for rapid sterilization and sets up convection currents which carry the surface water toward an overflow at the rear of the sterilizer. The continual rise in the water level, due to the expansion of the heating water,

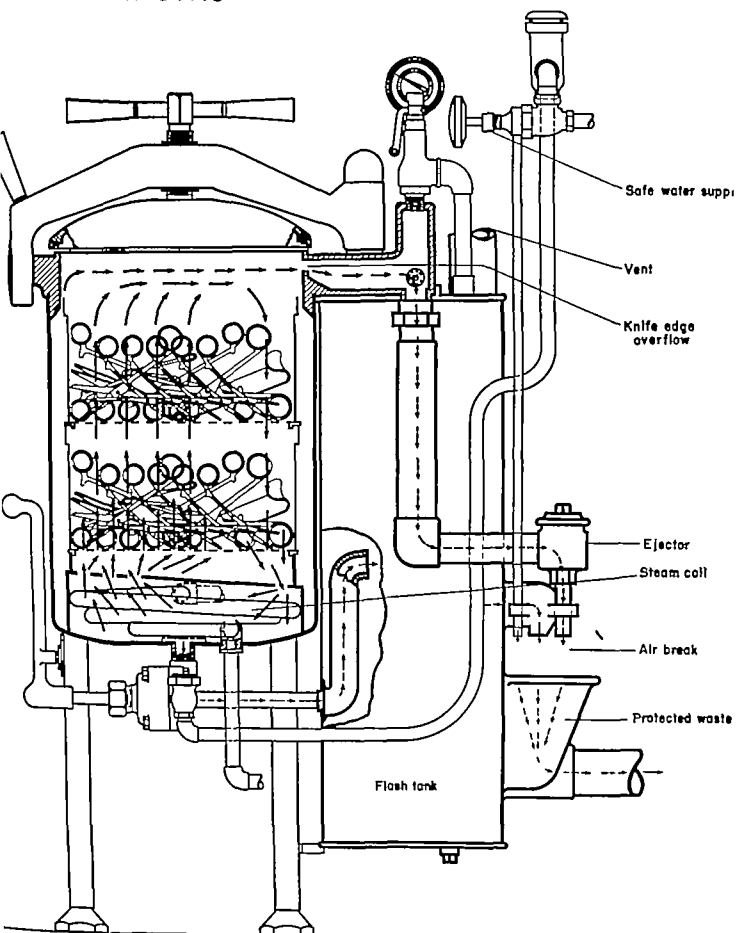
¹⁷ LANGMUIR, I. Oil Lenses on Water and the Nature of Monomolecular Expanding Films, *J. Chemical Physics*, 1 756-776, 1933

carries the oils and the scum formed by the blood and pus over a knife edge overflow into a reservoir, whence it is discharged into the drain by a special ejector. A suitable detergent ¹⁸ and water softener ¹⁹ is used in proper amounts to remove the soil and prevent the precipitation of a film of alkaline earth soaps and salts on the instruments and inhibit corrosion. The temperature of the water is raised to 132°C in seven minutes, a trip valve automatically shuts off the steam and a signal light indicates the attainment of sterilizing conditions, figure 110. After two minutes, the superheated water is rapidly drained into a flash tank, exposing the instruments to saturated steam.

¹⁸ HALL, R. E. *Washing and Cleansing* U. S. Patent No. 2,035,652

¹⁹ HALL, G. O. and SCHWARTZ, C. Sanitary Value of Sodium Metaphosphate in Dishwashing, *Ind. & Eng. Chem.*, 29 421, 1937

INSTRUMENT WASHER STERILIZER



PROCESS CHART INSTRUMENT WASHER STERILIZER

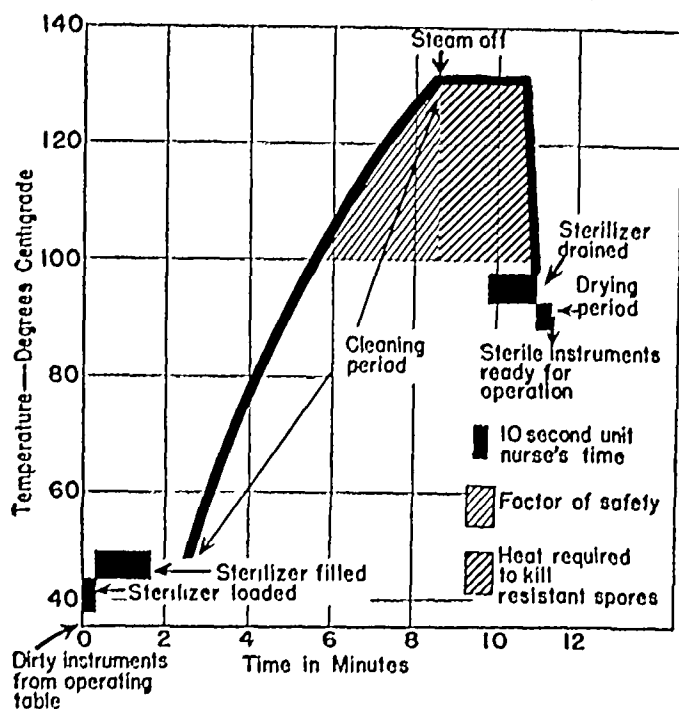


FIGURE 110

Waller¹⁶

for approximately one minute while the pressure is being relieved. The residual heat in the instruments is sufficient to flash most of the adherent moisture and the clean, dry, sterile instruments are ready for immediate use upon removal from the sterilizer.

A bacteriologically safe, but otherwise hazardous, technic for the terminal disinfection of instruments from septic cases is that of immersing the soiled instruments in a detergent solution and autoclaving them at 121°C for forty-five minutes. The danger of scalding the attendant who attempts to remove the container full of hot solution before it has cooled is ever present. Because there is no provision for disposing of the grease and scum that accumulates on the surface of the water, the instruments are usually dirty when removed from the sterilizer; the inside of the sterilizer is fouled by the accumulation of grease and scum that splatters on the wall when the pressure is relieved. Despite these disadvantages, some sterilizer manufacturers employ this principle.

CUTTING EDGES

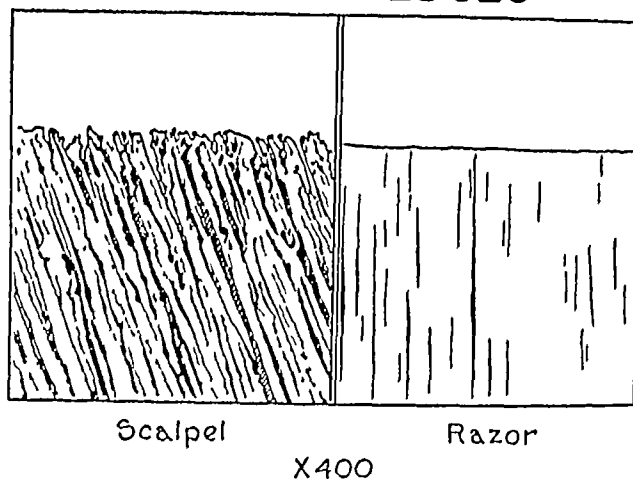


FIGURE 111

Peters²⁰

Soaking dirty instruments in a germicide, boiling for prolonged periods after thorough scouring and scrubbing, or combining such procedures in various ways is not only time consuming but also removes the instruments from circulation. What is of greater danger, spores may be spread throughout the operating room during the cleansing process or nonpressure sterilizers may be contaminated with an oily scum containing heat resistant spores.

THE STERILIZATION OF CUTTING EDGE INSTRUMENTS

There are two types of cutting edges which must be considered in surgery — the edge which cleaves and the edge which shears. The former is difficult to sterilize without spoiling the microscopic saw teeth which make it sharp. Figure 111 shows an enlargement of a scalpel edge (honed) on the left and a razor edge (polished) on the right. These edges corrode readily with a marked decrease in sharpness due to the concentration of electrolytic action on the saw teeth of the cutting edge. This is due to the fact that the current density is intensified at each microscopic tooth, just as lightning is attracted to a lightning rod and the tooth is quickly eroded away.²⁰

STERILIZING TRAY FOR CUTTING INSTRUMENTS

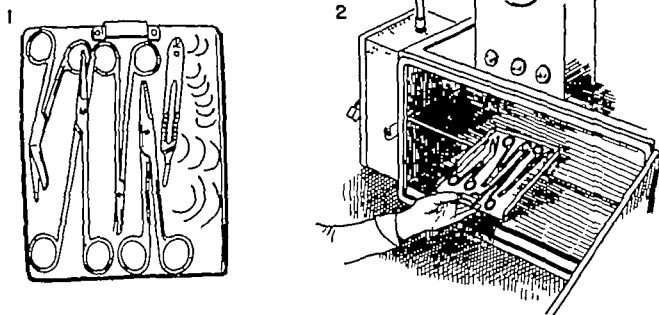


FIGURE 112

Walter ²¹

Dullness in itself does not necessarily indicate faulty sterilization. Many scalpels are improperly sharpened and come to the operating room with a marked feather left on the edge which breaks off and leaves a dull edge. Others are dulled by failure to protect the sharp edge during handling, storage or sterilization. Some surgeons dull the sharpest blade by careless contact against the tip of their tissue forceps or hemostats.

The shearing edge does not present such an acute problem because a hard, smooth bevel-edge blade is essential rather than the thin, keen edge of a scalpel. The edges of blades intended for rough work are almost right angled, those designed for cutting delicate tissues have sharper bevels. In either case, the shearing action results as the apposed blades close together. Hence, the alignment and apposition of the blades are as essential as sharpness for satisfactory cutting action. Poor apposition permits the blades to slide past each other with no

shearing action, too forceful apposition causes the blades to dig into each other, ruining their edges. Both troubles are man-made. The former results from using the scissors to cut materials heavier than those for which they were designed, so that the blades are sprung apart and the initial shearing adjustment is spoiled. The latter is due to faulty adjustment of the blades, habitual supplementing of the apposing force by a surgeon who is accustomed to using loose scissors and whose habit runs good scissors, nicks in the blades from cutting wire or bone that cause the blades to dig into each other. Properly ground scissors of good steel can be sterilized satisfactorily by either saturated steam or dry heat. Misuse causes poor function oftener than does faulty sterilization.

The ideal method for the sterilization of cutting-edge instruments is to expose them to dry heat for one hour at 160°C on an electrically heated aluminum plate. All the sharp instruments for each operation can be arranged on small aluminum trays for sterilization, figure 112 ²¹ If properly con-

²¹ PETERS, P. N. Measuring Sharpness of Razor Blade Edges, *Metal Progress* 24:18-22, 1933.

trolled, a hot air oven is also satisfactory. Cutting-edge instruments can be satisfactorily sterilized by exposing them to dry heat in the chamber of a dressing sterilizer for a minimum of four hours, or more conveniently, overnight. The oil sterilizer is an undesirable, messy, hazardous method of sterilizing cutting-edge instruments, even though it is bacteriologically sound.

Corrosion of cutting edges can be prevented in the steam sterilizer by submerging them in diethylene glycol containing 10% to 20% of water.²² The instruments should be arranged in shallow trays and exposed to saturated steam at 121°C for thirty minutes.

Chemical disinfection of cutting-edge instruments is satisfactory provided they are clean and dry when immersed and a sufficient period is permitted for germicidal action to occur (see Chapter IV).

Cutting-edge instruments can be sanitized with but moderate dulling by boiling for fifteen minutes in a 2% solution of sodium carbonate.

THE CARE OF HOLLOW NEEDLES

Three types of needle failure are inexcusable because they reflect gross carelessness on the part of those responsible for the maintenance of the needle. The most frequent fault is the needle that is plugged with accumulated dirt or blood. It is evidence of unforgivable laxity. Needles must be cleaned as soon as possible after they are used by reaming with a snugly fitting stilette and forcing hot detergent solution through the cannula. Particular attention must be paid to the inside of the hub where blood accumulates between the tip of the ground glass syringe and the bottom of the hub, figure

²² WALTEP, C. W. Sterilization, *Surg Clin N A*, New York Number, p. 353, April, 1942.

²³ HARVEY, S. and GARDNER, J. S. Diethylene Glycol as a Medium for Heat Sterilization of Surgical Instruments, *Yale J Biol & Med*, 14:547, 1942.

ure 207, 2. A tool can be obtained which fits the inner contour of the hub so that it will clean out this deposit.

A second source of failure is breakage where the cannula joins the hub, usually due to electrolytic thinning of the cannula so that it snaps off. Dullness or thinness can be detected by holding the hub firmly between the thumb and finger of one hand and springing the cannula gently through an arc. Weakened cannula will bend or snap off, figure 113, 7.

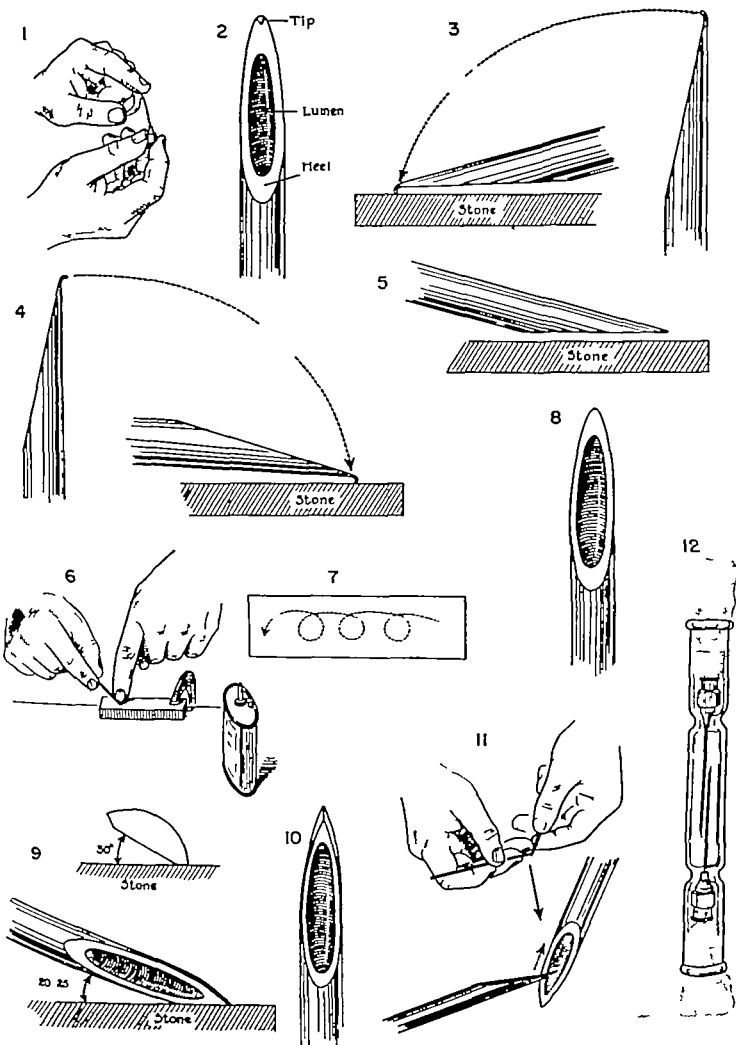
A third failure is the dull needle. Dullness may be due to several causes. Flat or blunt tips and sharp heels all interfere with good performance. With a little care, dull needles can be sharpened skillfully enough so that they simulate those which are sharp. The chief requirements are a thorough understanding of figure 113 and a few tools.* A coarse carborundum stone and a fine Arkansas oil stone are essential; also a magnifying glass which enlarges at least four times. A small handle for the needles can readily be made by attaching a Luer needle adapter to an old instrument handle. A liberal supply of light machine oil such as "3 in 1" should be on hand. A small carpenter's clamp is helpful in fixing the stone to the edge of the table so that both hands are free.²³

To sharpen a needle, it is attached securely to the handle and carefully inspected under the magnifying glass to identify the type of damage which has rendered it unfit for use. The majority of needles are discarded because the cutting tip has bent either inward toward the lumen of the cannula or outward away from the bevel, figure 113, 2, 3, 4. This hook must be ground off as the first step in repairing a bent needle. This is readily done by rubbing

* Becton Dickinson & Co., Rutherford, New Jersey.

²³ SCHWIDETZKY, O. Personal communication, 1943.

CARE OF HOLLOW NEEDLES



hooked portion on the coarser stone until the original contour has been restored, figure 113, 3-4. The stone must be oiled because the oil prevents clogging of the grinding surface, hastens sharpening, hinders the formation of burrs along the edge of the needle, and prevents the stone from leaving a rough surface.

Once the contour of the needle has been restored, the needle can be resharpened on the fine-grained oil stone. To sharpen it, the flat bevel of the needle is held flush with the stone 113, 5 and, with the index finger of the other hand pressing gently downward, figure 113, 6, the beveled edge is sharpened with several elliptical motions across the face of the stone, figure 113, 7. The needle is then inspected to make certain that the entire beveled surface is shiny and smooth, figure 113, 8. If the surface is not satisfactory, this step is repeated once more.

To produce a sharp cutting point which will penetrate skin and veins readily, the sides of the beveled point must be sharpened. This is done as is shown in figure 113, 9. Raise the needle so that its long axis is at an angle of 20 to 25 degrees with the surface of the stone, turn the bevel so that it lies at an angle of approximately 30 degrees with the stone and draw it carefully back and forth several times to bevel the side of the point. Repeat the procedure on the other side of the needle. The tip of the needle should then have the appearance of that shown in figure 113, 10. Inspect the needle carefully under the magnifying glass and remove any burrs from the edges with a burr picking tool. This tool is used by inserting it flat side up into the point of the needle and scraping any burrs from the beveled edge with the sharp edges of the tool, figure 113, 11. Burrs along the outer edge of the bevel are scraped away, care being used to scrape only from the point toward the heel of the needle.

Care must be taken to keep the stilettes of spinal needles forced in snugly during sharpening so that the bevel of the stilette matches that of the cannula perfectly.

After a needle has been sharpened, it can be tested easily by puncturing a piece of tightly drawn chamois. The needle must penetrate it smoothly and easily. When it is withdrawn, it must not stick in the chamois or catch the surface as it is pulled free. Inspection of the lumen sometimes shows it to be occluded with a small plug of chamois which was punched out by a sharp edge at the heel of the needle. This occurs either because a burr has not been removed or because the bevel is not flat. Needles which are sharpened inexpertly on a grinding wheel frequently have a curved oblique end with a radius sufficiently large for the heel to present like a cork borer to punch out a plug of skin which occludes the needle as it is introduced.

Sharp needles cannot be expected to remain so if they are sterilized and stored improperly. The sharp tips must be protected from mechanical dulling by protecting the needles during sterilization in an hour-glass tube as illustrated in figure 113, 12. Needles must not be sterilized with stilettes in place because the electrolytic action set up between the stilette and needle causes early corrosion and weakening. Needles are best sterilized in dry heat but can be sterilized successfully in saturated steam at 121°C. The only disadvantage of the latter technique is that the needles must be sharpened more frequently to keep their points keen. Chemical sterilization must be avoided because residual germicide in the cannula may cause tissue necrosis.

STERILIZATION OF GLASSWARE

Glassware is sterilized most satisfactorily in saturated steam, provided the glass has a

low thermal expansion such as characterizes boro-silicate glasses, Pyrex brand for example, so that spontaneous fracture due to unequal expansion is avoided. Properly annealed boro-silicate glass also has marked resistance to erosion by steam. Soft glass of the lead, potassium, or sodium variety or poorly annealed boro-silicate glass will gradually become frosted and cloudy when repeatedly exposed to saturated steam. Ground glass surfaces are readily attacked by steam, distilled water, or dilute alkali because the smooth annealed surface has been destroyed by the grinding. A frequently overlooked consideration in the selection of glassware is that its chemical composition must not affect solutions which are to contact it during sterilization or storage. Dextrose, procaine, and morphine solutions all deteriorate in the slightly alkaline pH at the solution glass interface of soft glass bottles.

The chief factor in the sterilization of glassware in the steam sterilizer is air clearance because unless a horizontal path is provided for the escape of air from flasks, bottles, and the like, the inner walls of the vessels are likely to remain unsterile. The water analogy, figure 55, demonstrates why this is so. Where dry glassware is desired, as for use in bacteriology, vessels must be inverted during sterilization. The sterilizer should be loaded and the glass preheated so that when the steam is admitted, there is a minimum of condensation. If the sterilizer door is left standing ajar with steam in the jacket at the close of the sterilizing cycle, the glassware will be dried in the course of thirty minutes. Where dryness is not essential, bottles and flasks can be sterilized in the upright position by adding sufficient water to purge the container of air. From figure 36, it will be recalled that 1 cc. of water turns into 865 cc. of steam. Hence, if 2 cc. of water are added to a liter

flask, sufficient steam will be generated to purge the air from the flask.

CARE OF GLASS SYRINGES

Most damage to syringes stems directly from carelessness on the part of those who use them. The chief fault is failure to clean syringes immediately after use. This results in the plunger sticking in the barrel or the needle sticking on the tip, when the residual solution dries or when the film of blood clots. Corrosion of the ground glass surfaces may occur and result in accelerated wear and leakage. To assure long, trouble free life, the syringe should be rinsed with tap water promptly and disassembled.

If the plunger sticks, several techniques for loosening it may be tried. The easiest is to boil the syringe in 25% aqueous solution of glycerine for ten minutes and to attempt removal of the plunger while the syringe is still hot. If blood has clotted in the syringe, it is readily leached out by soaking the syringe in a solution of "Haemosol"*. The most successful method is to use a syringe opener. The opener is filled with warm water and attached securely to the frozen syringe. Firm, steady pressure is applied to force water to infiltrate between the plunger and the barrel and release the former, figure 114-7.

To loosen a frozen needle, dip the hub of the needle in boiling water long enough to cause it to expand away from the cold glass syringe tip and pull it off. If this technic fails, boil the syringe in 25% glycerine solution and remove the needle while it is hot.

Syringes are cleansed by washing in cold running water. Alkalies, detergents, and soap must be avoided because they deposit alkali earth soaps on the ground glass surfaces and cause the syringe to bind. If

Melroeck & Co. N. Y. C.

CARE OF SYRINGES

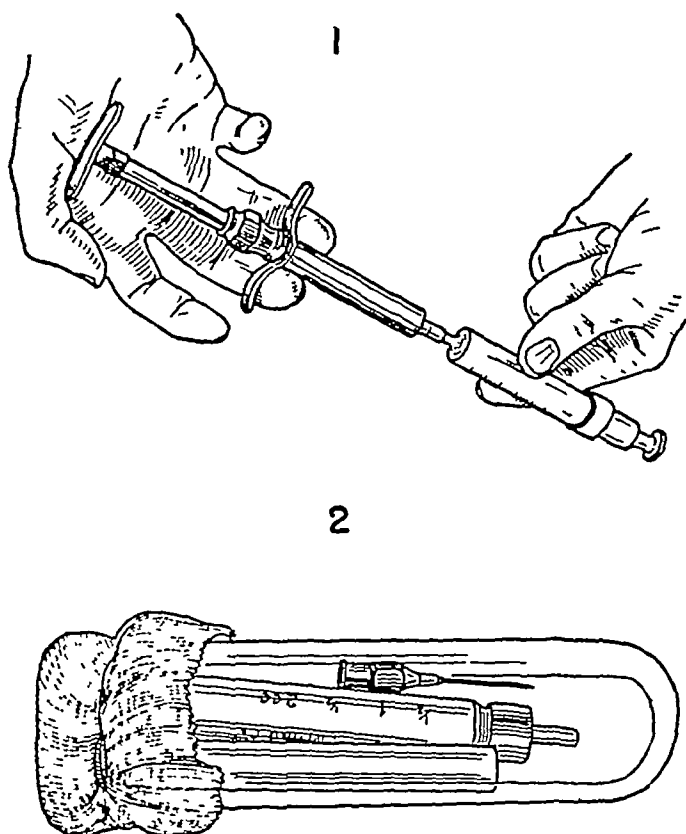


FIGURE 114

syringes are to be sterilized by dry heat, they are air dried and assembled, taking care to match the serial numbers of barrel and plunger. Oil can be removed from syringes by immersing them in a high flash solvent, such as "Stod Sol"

Glass syringes are best sterilized by using dry heat. Exposure to 160°C for one hour is ideal. An alternate technic is to subject them to the dry heat at 121°C in the chamber of a dressing sterilizer in which steam pressure is maintained in the jacket overnight. Small syringes can conveniently be packaged in test tubes covered with cellophane or paper flaskhoods, figure 114, 2. If saturated steam must be used, corrosion can be kept at a minimum by thoroughly preheating the glassware. The syringes should be disassembled to expose the barrel and plunger to the steam and also to avoid

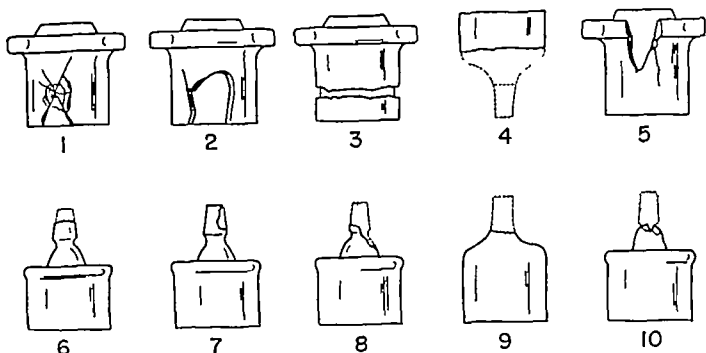
bursting fractures which occur because of uneven cooling when the steam is vented quickly. Such fractures are caused by the barrel cooling more rapidly than the plunger and shrinking on the latter with the result that the barrel bursts.

Various types of syringe breakage are illustrated in figure 115 so that damage due to careless handling can be recognized and checked. The impact break is caused when a heavy object falls on a syringe, figure 115, 1. The blowout break is caused by sterilizing the plunger and barrel together, figure 115, 2. This will happen repeatedly in a properly functioning steam sterilizer. When unclean parts are boiled together, such damage also occurs. Figure 115, 3, typifies breakage due to improper annealing of glass during manufacture. The result of letting go the plunger after it has been partially withdrawn with the tip occluded is shown in figure 115, 4. The negative pressure is sufficient to snap the plunger against the end of the barrel and shatter it. The result of inserting the plunger out of line and wedging it in the barrel is illustrated by figure 115, 5. Crushed tips are caused by jamming into the hubs of improperly fitting needles, figure 115, 6. The split tip results from forcing too large a wire or needle through the hole in the tip, figure 115, 7. Too much lateral pressure exerted against the needle will result in the break shown in figure 115, 8. Lateral pressure on a poorly annealed or improperly ground tip will also break the tip, figure 115, 9. A jagged break results from an attempt to twist off a stuck needle, figure 115, 10.

STERILIZATION OF RUBBER

The sterilization of rubber is a subject which cannot be discussed from a general point of view because there are many different types of rubber, each compounded for

TYPES OF SYRINGE BREAKAGE



Becton, Dickinson and Company

FIGURE 115

a special purpose so that arbitrary rules cannot be applied. Deterioration of rubber compounds is influenced by many factors. Age alone causes deterioration which is accelerated by heat and exposure to light. Soiling with various chemicals such as oil, grease, or benzine or exposure to oxygen shortens the life of rubber. Some types of rubber imbibe water quickly. Thus, the ordinary vulcanized rubber glove imbibes sufficient water during sanitization in boiling water to increase its size and decrease its tensile strength perceptibly. The cresol group of germicides destroy rubber as do many of the halogen compounds. Latex rubber, in particular, deteriorates rapidly in contact with copper and its salts.

Synthetic rubber has already found its way into the operating room for special purposes and articles fabricated of Neoprene or Koroseal have given satisfactory service.

It is more logical to select a type of rubber which will meet the requirements of oper-

ating room use, including that of sterilization, than it is to devise sterilizing techniques to overcome the faults of improperly selected rubber articles. For example, latex rubber tubing withstands sterilization poorly. Five or six trips through the sterilizer cause sufficient deterioration to make it unfit for use, yet rubber tubing can be purchased which will withstand 75 trips through the sterilizer before its usefulness becomes questionable. The wisdom and economy of selecting the latter type is obvious.

RUBBER GLOVES

The fact that one third of the gloves used in the operating room at the Peter Bent Brigham Hospital are punctured each time they are used dictates the selection of rubber gloves on the basis of low first cost rather than on quality intended for repeated sterilization. Others have reported comparable experience with glove puncture.¹⁴ Because patched gloves are awkward and unreliable,

they are rejected in the operating room and used elsewhere in the hospital.

The chore of caring for rubber gloves can be lessened by gaining the cooperation of the surgical team. Blood and pus must be washed from the gloves before they are removed. This can be done in the hand basin used during the operation, if the gloves have been potentially contaminated. Otherwise, the scrub sink may be more convenient because a brush can be used to loosen dried blood.

The clean gloves are then rinsed in running water and tested for punctures. This is quickly done by suspending the glove by either side of the cuff so that it assumes its natural shape, figure 116, 1. The cuff is then closed and rolled on itself to trap the air inside the glove, figure 116, 2. The glove is then twirled to distend it, figure 116, 3, and either submerged in water to disclose the stream of bubbles that escape from a puncture, figure 116, 5, or held up to the face to reveal the air spurting from the hole, figure 116, 6. The intact gloves are then hung over three-eighths inch wooden pegs to dry, figure 116, 7. Moderate warmth will hasten drying but exposure to sun, the air over a radiator, or the hot air in a sterilizing room will damage the rubber. Some hospitals are equipped with steam heated glove dryers akin to the blanket warmer where gloves are rapidly dried in a current of air warmed to 50°C. When thoroughly dried, the gloves are powdered and sorted according to size.

Dusting powder is used to prevent adhesion of apposing surfaces of gloves during sterilization and to facilitate putting them on when the dry glove technic is used. Because residual talcum powder has been demonstrated to stimulate a granuloplastic

response in wounds^{25, 26, 27} or in the skin of the surgeon's hands, the choice of a powder must be carefully considered. The surgical team must be schooled to wash their gloved hands carefully before approaching the operative field. The air of the operating room must also be kept free of powder by meticulous care in applying it to the skin so that excess powder is not spread about in the air and on the floor. Potassium bitartrate has been shown to be effective and is not altered by sterilization^{28, 29}. It deteriorates rubber however. A mixture of amylase and amylase pectinates, sold under the trade name "Biosorb,"* protects rubber, withstands sterilization, and is innocuous to skin and causes no tissue reaction³⁰. The sterilization of powder has long been recognized as a problem and postoperative infections have been traced directly to the use of unsterile powder^{31, 32}. Powder has such excellent insulating properties that steam cannot flow into it, hence it is impractical to sterilize powder in the usual shaker can. In one hospital, it was demonstrated that twenty-four hours' exposure to saturated steam was necessary to bring the temperature of the powder to sterilizing levels.

²⁵ GERMAN, W. M. Dusting Powder Granulomas Following Surgery, *Surg, Gyn & Ob*, 76:501, 1943.

²⁶ BYRON, F. X. and WELCH, C. S. Complication from Use of Glove Powder — (Talc Nodules in Surgical Scars), *Surgery*, 10:766, 1941.

²⁷ McCORMICK, E. J. and RAMSEY, T. L. Postoperative Peritoneal Granulomatous Inflammation Caused by Magnesium Silicate, *J A M A*, 116:817, March, 1941.

²⁸ SEELIG, M. G. Dusting Powder for Rubber Gloves, *J A M A*, 123:113, September 11, 1943.

²⁹ SEELIG, M. G., VERDA, D. J. and KIDD, F. H. The Talcum Powder Problem in Surgery and Its Solution, *J A M A*, 123:950-954, December 11, 1943.

³⁰ LEE, C. M. Experiments with Non-irritating Glove Powder, *Bull Am Coll Surg*, February, 1947.

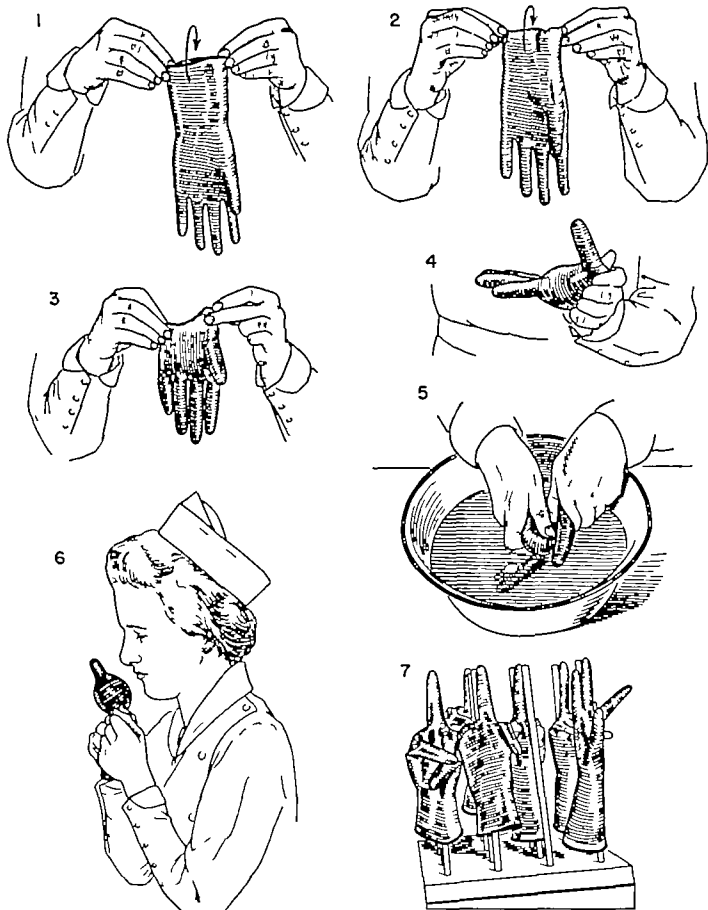
³¹ CAIRNS, H. Bacterial Infection during Intracranial Operations, *Lancet*, 1:1193-1198, May, 1939.

³² ASCROFT, P. B. The Control of Sepsis in a Hospital in North Africa, *Lancet*, 1:594, May, 1944.

* Johnson and Johnson, New Brunswick, New Jersey.

³³ DEVENISH, E. A. and MILES, A. A. Control of Staphylococcus Aureus in Operating Theatre, *Lancet*, 1:1088-1094, May, 1939.

CARE OF SURGICAL GLOVES



Powder can be readily sterilized if the granules are dispersed in the meshes of a gauze sponge. One cc folded into the sponge can be sterilized safely along with the gloves, figure 117. The folded sponge containing powder can then be used as a puff for the easy application of the powder at operation. The puff prevents excess powder from getting on the floor. Envelopes containing powder are too difficult to sterilize by steam to warrant their use.

Gloves should not be sanitized by boiling because they imbibe water and lose tensile strength, elasticity, and shape. In addition, they must be sterile because of their continual contact with the wound. Gloves withstand sterilization by saturated steam but deteriorate rapidly in mixtures of air and steam. To assure minimal exposure to air, gloves are wrapped so that the horizontal path for the escape of air, demonstrated in the water analogy, figure 55, 5, is always present.

A convenient method for wrapping gloves for the wet glove technic is shown in figure 118. Sterilizing folders, made much like letter folds, with tongues that can be inserted into the palm of the glove to assure air clearance, figure 118, 7, are used. The cuffs of the gloves are rolled back, figure 118, 2, and the paired gloves are slipped one into each pocket of the wrapper, figure 118, 3 and 6. Care must be taken to have both thumbs in the depths of the pockets and to avoid folds or wrinkles in the fingers which might trap air. A tab is then inserted into the palm of each glove, figure 118, 4, 5, 7, and the folder is closed, figure 118, 8, 9. The size of the gloves is marked on the outside of the wrapper, figure 118, 10.

Up to six folders of gloves are then packaged in the sterilizing wrapper shown in figure 119, 7. The wrapper is spread on the table with the folded corner nearest the

worker. The folders are stacked in the center of the wrapper so that their folded edges will present to the worker. This places the thumbs of the gloves above each other, figure 119, 2. A typical bayonet wrap is then done, figure 119, 3 to 7. The package is tied with spool tape, figure 119, 8, and labeled, figure 119, 9. Packages of gloves wrapped as illustrated are sterilized standing on the edge indicated by the pointed corner of the cover, figure 119, 10, which insures the thumbs being uppermost for prompt air clearance.

Gloves intended for use in the dry glove technic may be packaged for sterilization in envelopes shown in figure 120, 1. Folded gauze sponges are inserted into the cuffs, figure 120, 2, to assure the ready exchange of steam for air. One of these sponges contains 1 cc. of powder, figure 117. The paired gloves are inserted, thumbs uppermost, into the pockets of the sterilizing envelope, figure 120, 3. A towel, folded as in figure 96, 4, is inserted between the leaves of the envelope as it is closed, figure 120, 4. Each envelope is wrapped and labeled, figure 119. An alternate technic for dry gloves utilizes the folders described in figure 118. The sponge containing the powder and a folded towel are enclosed, figure 121.

Rubber is best sterilized in the upper two thirds of the steam sterilizer so that residual air does not contact it. A suitable rack or wire grill can be obtained to support the gloves. To avoid the prolonged exposure essential for penetration of large bundles or the heating of flasks of solution, rubber goods should be sterilized alone. When wrapped loosely and positioned properly, saturated steam contacts the entire surface of the rubber instantly and, accordingly, the sterilizing cycle consists chiefly of that necessary to destroy resistant spores. Fifteen minutes' exposure at 121°C suffices for this,

PREPARING POWDER FOR DRY GLOVE TECHNIC

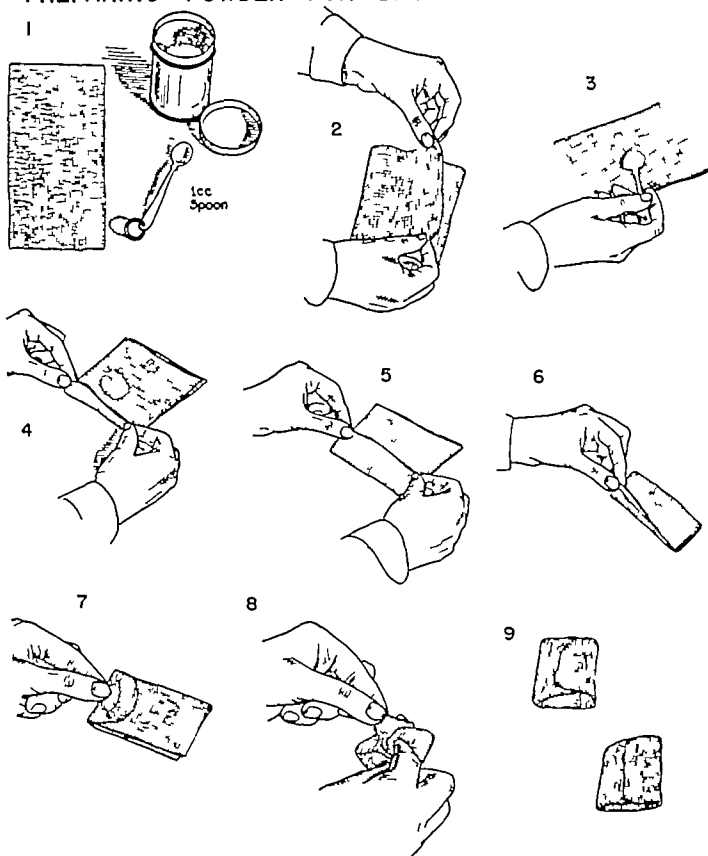
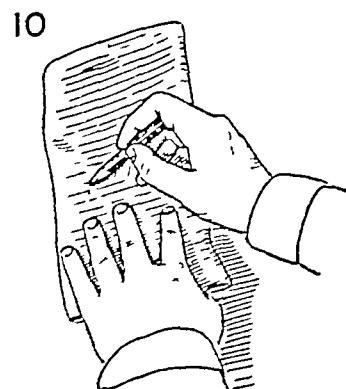
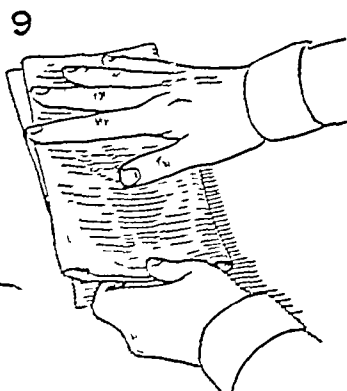
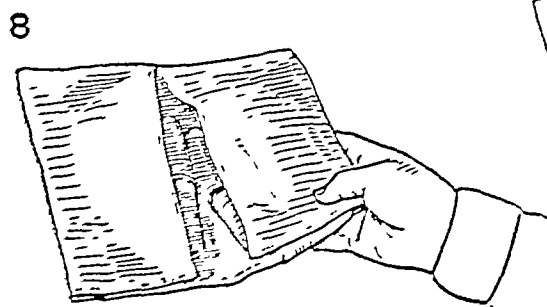
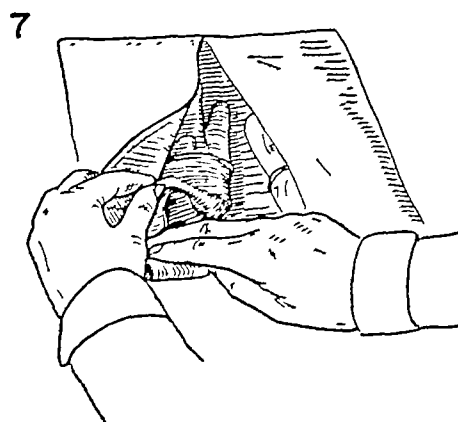
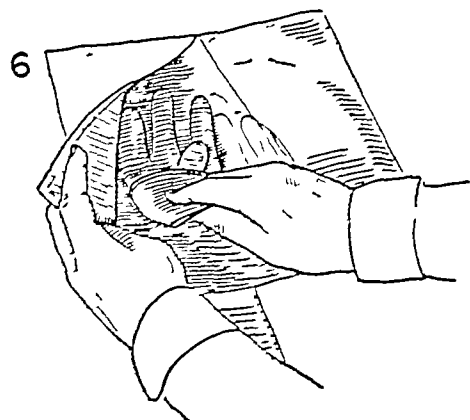
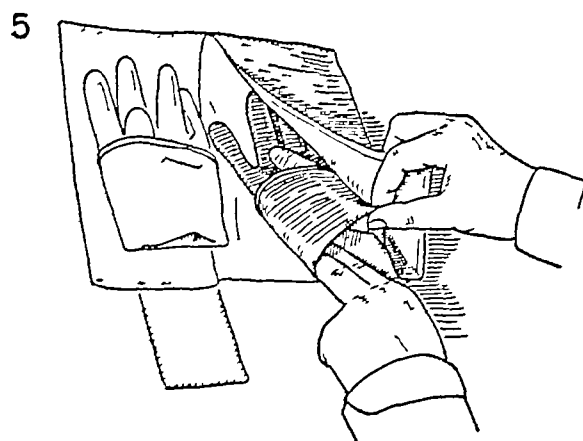
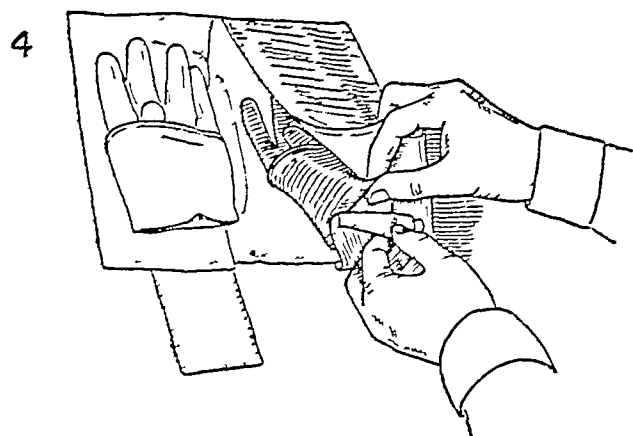
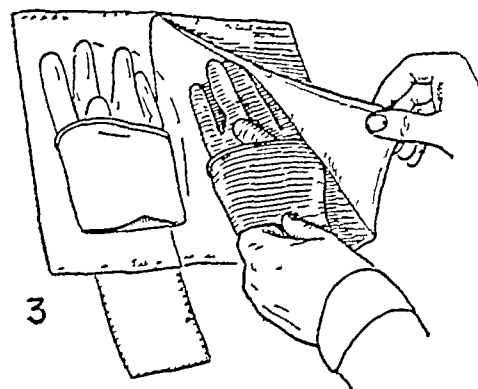
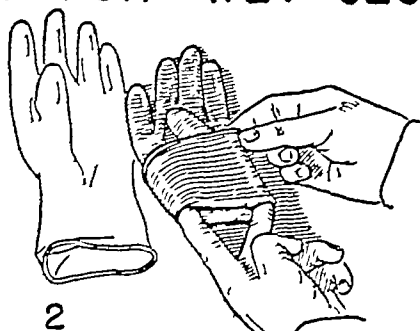
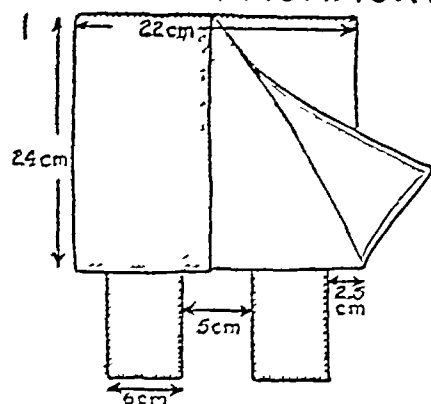
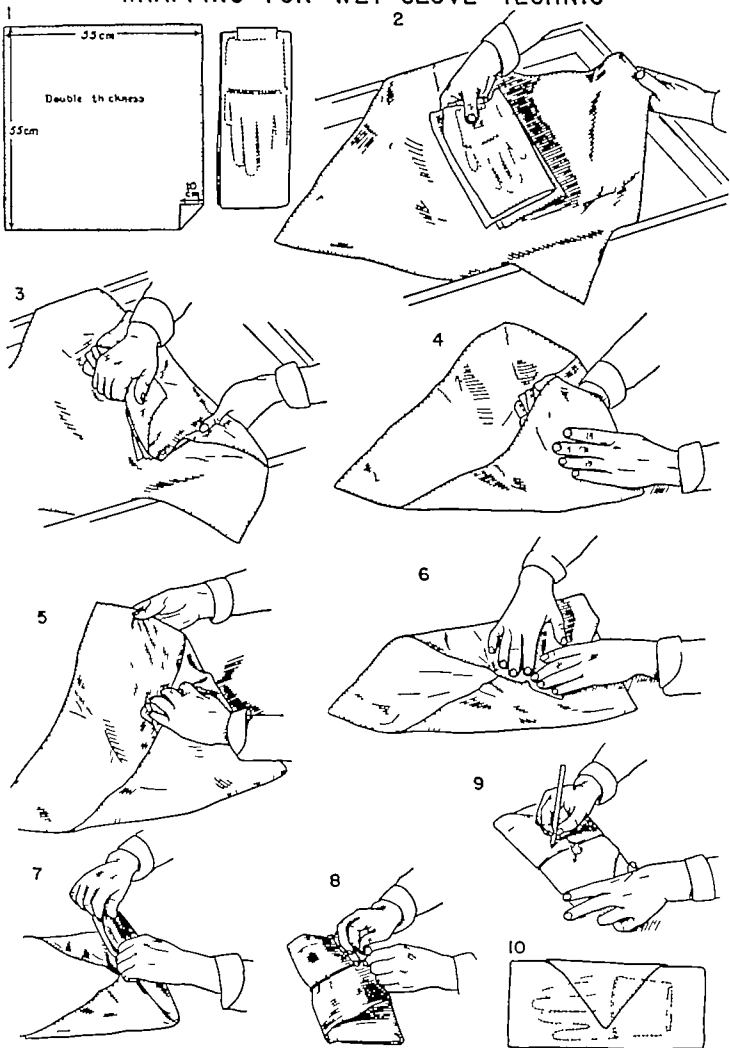


FIGURE 117

PACKAGING FOR WET GLOVE TECHNIC



WRAPPING FOR WET GLOVE TECHNIC



PACKAGING FOR DRY GLOVE TECHNIC

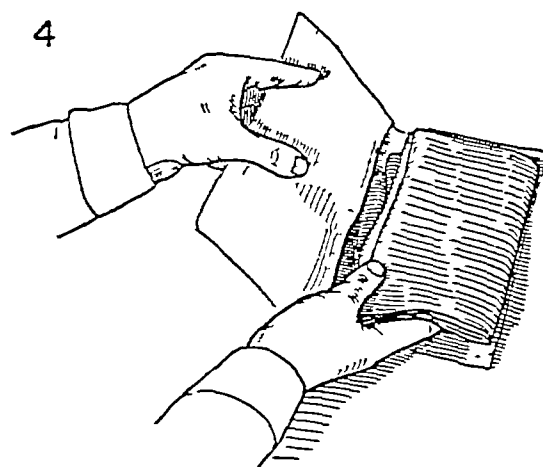
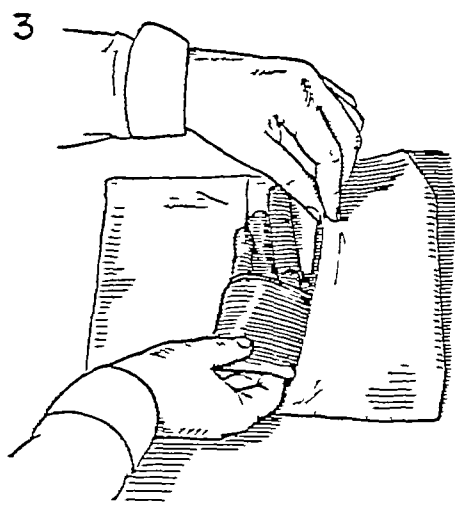
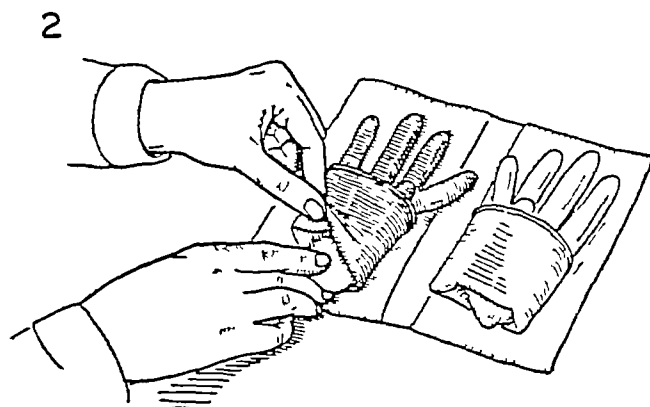
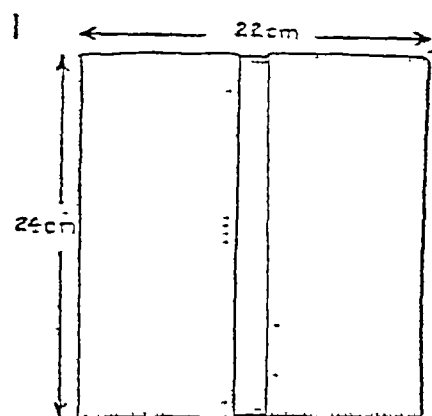


FIGURE 120

figure 37. At the Peter Bent Brigham Hospital, however, standardization has been found so advantageous that a thirty-minute exposure is enforced just as for dry goods. Excessive deterioration of rubber has not been experienced and the rigid control of personnel essential to make the fifteen-minute exposure safe has been avoided.

The sterilization of rubber tubing presents special problems in air clearance which are discussed in Chapter XVI.

Penrose tubing of good quality can be sterilized as are rubber gloves. Many thread braided gauze ("Surgitube"*) through the tubing prior to sterilization so that "cigarette" drains are instantly available.

* Surgitube Products Corp., New York City.

Rubber sheeting is best sterilized by laying it on a piece of single-thickness muslin and rolling the two into a cylinder. The cylinder is wrapped and sterilized on end so that the air can escape. Folded rubber sheeting is treacherous because air pockets among the folds.

USE AND STERILIZATION OF PLASTICS

The wide range of plastic materials, all possessing characteristic physical properties which make the use of a specific plastic advantageous, necessitates a discussion of the chief types so that the user can correlate stability in heat and solvent resistance with sterilizing practices. Most plastics are de-

from synthetic materials and are not

ALTERNATE DRY GLOVE PACKAGING TECHNIC

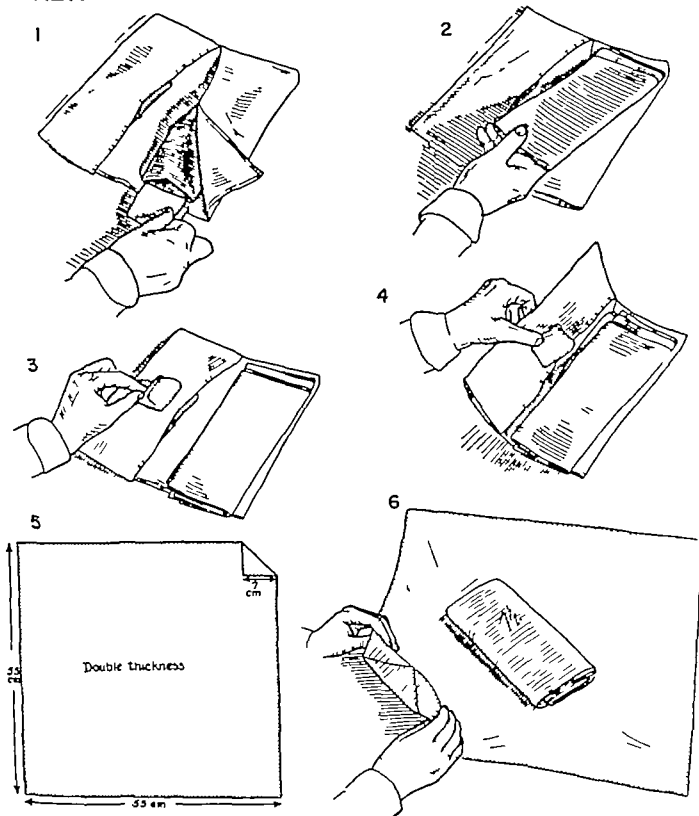


FIGURE 121

Fig 122 PLASTICS LIKELY TO

TYPE AND TRADE NAME	COMPOSITION	OUTSTANDING PROPERTIES
Phenolic Resins Moulded Durez Resinox	interaction phenols, aldehydes, or ketones in presence of catalyst	heat resistant, chemical resistant, low frictional, nonsqueak
Furfural Durite	interaction of phenol and furfural obtained from oat hulls and corn cobs	chemically inert, high heat resistance, superior electrical properties
Phenolic Pulp Kysite	preformed pulp products impregnated with phenolic and compacted	tensile strength in thin sheets, non-shatterable
Phenolic Asbestos Haveg	phenolic formaldehyde, resin and acid; digested asbestos fiber	resistant to physical and thermal shock, resists chemicals
Cast Phenolic Resins Catalin Catavar	cross-linked polymeric phenolic resins that are hydrophilic and can be cast with pressure and set by exposure to 80°C	high tensile and impact strength, rigidity, noninflammable, nonabsorbent, odorless, tasteless, transparent
Urea Resins Beetle Plaskon	urea-formalin condensation product used to impregnate cellulose fillers	odorless, tasteless
Melamine Resins Melmac	a trimer of cyanamide	arc resistant, odorless, tasteless, inert
Aniline Formaldehyde Cibanite Dilectene	divers condensation products of aromatic amines (benzedine) and aldehydes	electrical stability
Cellulose Acetate Lumarith Vinylite Plastocele	solution of cellulose acetate in various plasticizers	thermoplastic, great mechanical strength, transparent
Cellulose Acetate Butyrate Rezemite	solution of cellulose acetate and butyrate in plasticizer	low moisture absorption, good weather resistance, high impact strength, filament formations
Cellulose Nitrate Nitron Pyralin Celluloid Pyroxaline	cellulose esterified in mixture of nitric and sulfuric acids and plasticized in camphor	water resistant, tough, can be cemented easily, inflammable
Ethyl Cellulose Ethocel Ethofol	cotton linters or wood pulp treated with strong alkali or chlorinated alcohol	water resistant, tough, resists low temperature
Acrylic Resins Lucite Plexiglass Crystallite	polymerized derivatives of acrylic acid	superior transparency, water resistance, rigidity, lightness, transmits light, thermoplastic
Regenerated Cellulose Cellophane	cotton linters treated with sodium hydroxide and carbon bisulphide, prior to extrusion into ammonium sulfate to make sheet flexible, it is saturated with glucose, glycerol, or polychloroxyl alcohols	

BE FOUND IN A HOSPITAL

HEAT AND SOLVENT RESISTANCE	HOSPITAL USES
198 C (mineral filler), decomposed by strong alkali, resists organic solvents	bottle caps, oxygen mask parts
198°C (mineral filler) decomposes with weak alkali, resists organic solvents	electrical articles and parts
100°C, decomposed by strong alkalis, inert to organic solvents	bottle caps, dishes, trays
130°C, resists organic solvents	chemical apparatus
71 C (no filler) 130°C (asbestos filler) darkens in sunlight, decomposes in strong alkali, resists organic solvents	kitchen utensils, brush backs, instrument dials
insoluble in H ₂ O and organic solvents, decomposes in alkali, 76 C, decomposes strong acids	bottle caps, water resistant paper coatings, dishes
98°C (cellulose filler) 190°C (asbestos filler) decomposes in strong acids	tableware, buttons, electrical parts
82 C, darkens with sunlight, decomposes in strong acids, attacked by some organic solvents	artificial hard rubber electrical parts
60°-104°C, decomposes in strong acid decomposes in strong alkali, soluble in ketones, esters, and alcohols	combs, toothbrushes, fountain pens, pencils, spectacle frames, telephone and razor parts, tool handles, pens/pencils
60°-104 C, decomposes in strong acids, decomposes in strong alkali, soluble in ketones, esters, and alcohols	toothbrush handles, shaving brush handles, refrigerator hardware, counter nosing and edging shoes
60°C, decomposes in strong acids, decomposes in strong alkali, soluble in ketones, esters, and alcohols	spectacle frames, badges, buttons, collodion, tooth brush handles, toilet seats
60°-104°C, decomposes in strong acids, soluble in organic solvents	ice trays, paper coating goggle frames, tubing
48°-70°C, distorts at 51 C, soluble in ketones, esters, and aromatic hydrocarbons	lenses, dentures, illuminating instrument dials, gauge glasses, alloplastic material ²⁷
	wrapping material, dialyzing membrane

FIG 122 PLASTICS LIKELY TO

TYPE AND TRADE NAME	COMPOSITION	OUTSTANDING PROPERTIES
Moisture-proof Cellophane	sheet saturated with solution of cellulose nitrate, a plasticizer such as tri-cresyl phosphate, and various resins and waxes	
Alkyd Resins Amberlac Dulux Glyptol Esterol	alkyd esterification with self, with linolylic acid, or resin	hard brittle glasses to soft rubbery gums, good film builder
Vinyl Ester Resins Gelva Vinyon Fiber Koroseal	polymerized vinyl acetate or chloride	corrosion resistant, rubber-like materials
Polyvinyl Alcohols	hydrolyzed vinyl acetate	high tensile strength films, impregnable to oxygen and nitrogen, resistant to oil and grease
Vinyl Acetal Resins Alvar Saflex Vinylite X Formvar Butacite	condensation products of polyvinyl acetate and aldehydes	clear, transparent, adhesive, extensive, flexible stable films
Vinylidene Chloride Resins Saran Vec Velon	polymerized and copolymerized dichloroethane derivatives as by-product in cracking petroleum	waterproof, flexible, tasteless, nontoxic, chemical resistant, resists living organisms, noninflammable
Styrene Resins Styramic Styron Lustron	ethyl chloride and benzene react to ethyl benzene which is cracked to form styrene: heat, light, and catalysts cause it to polymerize to resin	resistant to chemicals, high index refraction, transparent, transmits light, excellent electric insulator, will not support combustion
Shellac Complac Composite	resinous incrustation secreted by the scale insect <i>Laccifer lacca</i> Kerr of British India	oil resistant, good electric insulation, excellent adhesive, high gloss
Casein Ameroid Galorn	skim milk digested with rennet enzyme	hygroscopic, noninflammability, translucent
Coumarone-Indene Resin Cumar Nevillac Paradene	polymerized indene and coumarone obtained from coal tar	high electrical breakdown, nonsaponifiability
Bagasse Molding Compound Valite	residue after extracting juice from sugar cane, 18% lignin, 45% cellulose	
Nylon Resins	polymeric amides with protein-like formula derived from coal, water, and air chemically similar to hair, silk, and wool	fabricated into sheets, fibers, and bristles extreme toughness, low water absorption, good flexibility, high tensile strength nontoxic

BE FOUND IN A HOSPITAL (Continued)

HEAT AND SOLVENT RESISTANCE	HOSPITAL USES
	granuloma stimulating substance ²⁴ alloplastic material for arthroplasties, ²⁵ dispensable tubing for parenteral fluids, flaskhoods
	synthetic finishes for automobiles, refrigerators, stove enamel, etc. waterproofing cloth
54-65°C, acetate — odorless, tasteless, nontoxic, soluble in ketones and alcohols chloride — chemical resistant tough noninflammable, resists soap, soluble in ketones	finishes, adhesives, water resistant hospital sheeting wood putty transcription records, electric cable insulation, rainwear
decompose 93°C, dissolves in weak acid, attacked by strong acid, dissolves in alkalis, unaffected by organic solvents	oxygen tents, protective film for skin, ²⁶ support for polaroid films
stable to light and heat, resists solvents and diffusion of gases	safety glass, cloth coatings, gas impermeable fabrics, rainwear
71-93°C, resists solvents, strong acids, and alkalis	furniture webbing and covers, screening
65-87°C, distorts at 79°C	dishes, bottle caps for corrosive chemicals, refrigerator parts, medical and surgical equipment, plastic windows, and bassinets
54°C, soluble in ketones, esters, and alcohols decomposes in strong acids and alkalis	varnishes, gum elastic catheters, telephone sets, phonograph records
softens 93°C, decomposes in strong acids and alkalis, softens in weak alkalis, resists organic solvents	buttons, bassinets
acid, alcohol, alkali, and brine resistant	mastic floor tile transcription records, chewing gum, waterproof duck
176-204°C, resists acids, alkalis, and solvents	screw cap closures
softens at 232°C, attacked by oxidizing acids, resistant to common solvents	suture material, bristles, catheters, nonadherent protective for wounds, dental floss

FIG 122 PLASTICS LIKELY TO

TYPE AND TRADE NAME	COMPOSITION	OUTSTANDING PROPERTIES
Vinyon	unplasticized vinyl resin is dissolved in acetone and squirted through nozzles to make filaments	good tensile strength, not lost when wet, water resistant, thermoplastic at 65°C, shrinks 12% on cooling
Cellulose Acetate Rayons	cellulose acetate dissolved in acetone is squirted through small holes into a warm air wheel and coagulates the rayon in fiber form	lustrous or dull finish, dimensional stability, water resistant, high tenacity
Neoprene	acetylene gas is combined with hydrogen chloride to form chloroprene, thousands of different rubber-like compounds can be compounded	properties can be varied over wide range to suit end use, high tensile strength, resilience, elasticity, abrasion resistance, oil and ozone resistance, ages well and withstands exposure to sunlight
Koroseal Korojel	plasticized polyvinyl chloride	properties vary with plasticizer, soft gels to hard material possible, tensile strength and elasticity good, resists action of soap, excellent flex resistance
Thiokol	interaction of organic halides and inorganic polysulfides compounded and vulcanized to simulate rubber	unique resistance to solvents and sunlight, less permeable to carbon dioxide, hydrogen, and helium
Resistoflex	modified polyvinyl alcohol resin compounded and cured to imitate rubber	resists attack by gasoline and organic solvents, good tensile strength and resistance to abrasion and flexion, is most impermeable of synthetics to organic liquids and gases
Ameripol	a group of synthetic rubbers compounded from butadiene and its copolymers	
Hycar	butadiene copolymerized with styrene and acrylonitrile in emulsion phase to form latex similar to latex	extreme resistance to oil, heat, aging, abrasion, and gases, soft to bone hard materials
Chemigum	copolymers of butadiene	resists solvents and oils better than rubber
Butyl Rubber	copolymer of isobutylene with diolefin	resists chemical attack, ages well, resists copper and other heavy metals and their salts

²⁴ GURDJIAN, Z. S., WEBSTER, J. E. and BROWN, J. C.: Impression Technique for Reconstruction of Large Skull Defects, *Surgery*, 14: 876, 1943

²⁵ PEARSE, H. E.: Experimental Studies on the Gradual Occlusion of Large Arteries, *Ann. Surg.*, 112: 923-937, 1940.

²⁶ MCKEEVER, D. C.: The Use of Cellophane as an Interposition Membrane in Synovectomy, *J. Bone and Joint Surg.*, 41: 576-580, 1943

²⁷ DEBAKEY, M., GILES, E. J. and HOWARD, E.: The Protection of the Operative Field with an Impermeable Adhesive Skin Coating — A Preliminary Report, *Surg., Gyn. & Ob.*, 74: 499, 1942

BE FOUND IN A HOSPITAL (Continued)

HEAT AND SOLVENT RESISTANCE	HOSPITAL USES
48°-65 C, chemical resistant, soluble in ketones and esters, swells in aromatic hydrocarbons	dental floss, filter cloth, screen cloth, shoes
60°-104 C, decomposes in strong acids and alkalis, dissolves in ketones, esters, and alcohols	protective dressings
130°C	rubber gloves, rubber stoppers, catheters, pessaries
65 C, soluble in ketones and esters	flexible molds, tubing film, catheters, bougies
	oxygen tent parts
	hose, tubing gloves, vial stoppers
	gas masks, resuscitator parts
flexible at -45°--148°C, resists 140°C	rubber sponge, soles, heels, bushings, stoppers
	tubing resistant cloth, gas masks

* BURMAN M and ABRAHAMSON, R. H. The Use of Plastics in Reconstructive Surgery. *Lucite in Arthroplasty*. *Mil Surgeon*, 93:405 1943 Abstr — *Internat Abstr Surg.*, 78:430 1944

Note A critical study of plastics as alloplastic materials too recent for inclusion in this table is

Ingraham F D Alexander E. A. Jr Matson, D D Synthetic Plastic Materials in Surgery *A.E.J.M.* 236:362-368 1947 *A.E.J.M.* 236:402-407 1947

tives, natural resins, or protein aggregates. These substances are known as binders. Other basic compounding materials include fillers, plasticizers, dyes, lubricants, and solvents. Various fillers may be added to binders to obtain qualities that the resin itself does not have, for example, high electrical, chemical, impact, or heat resistance. Typical fillers are wood flour, cotton fabric, graphite, asbestos, and mica. Plasticizers are added in some instances to increase flow properties for ease of molding, in others to increase impact strength. Plasticized resins lose some of their inherent tensile and compressive properties. Typical plasticizers are the sulfonamides, phthalyl glycolates, or triphenyl phosphates. Figure 122³³ lists the principal plastics encountered in hospitals. The resumption of civilian production will bring many new materials and many new plastic products to the hospital.

STERILIZATION OF SUTURE MATERIAL

Surgical gut is of two varieties. One, the boilable or anhydrous type, can be sterilized just as are surgical instruments. The other, nonboilable or hydrated type, must not be heated because the resulting hydrolysis ruins the gut. Tubes of the latter type are disinfected by chemicals.

Silk, nylon, and cotton suture materials are best sterilized in saturated steam at 121°C. Precautions must be taken to hydrate the suture material before it is put in the sterilizer by dipping the fingertips into water and moistening the strands to prevent superheating. Because these fibers shrink when moist, they should not be sterilized tightly wrapped about a nonyielding object such as a spool or board. A nice technic is to wrap the desired number of strands about a reel such as is shown in figure 123, 3, 4.

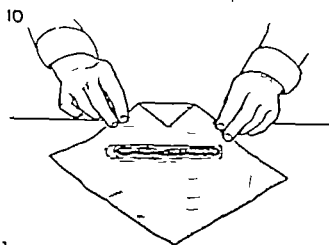
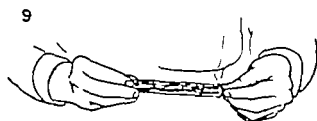
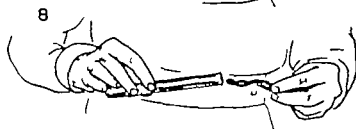
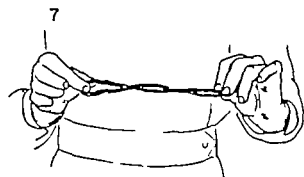
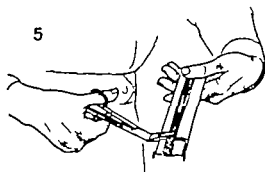
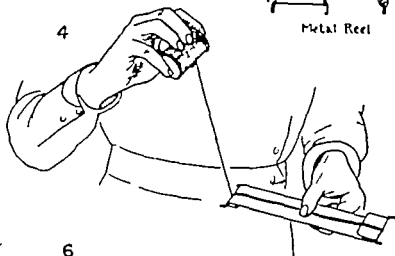
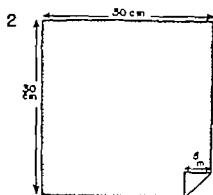
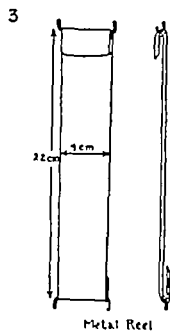
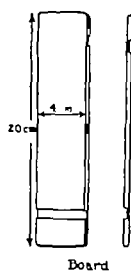
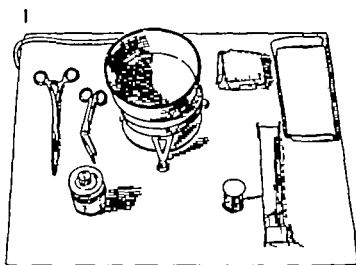
³³ Plastics Catalogue, 1945. Plastics Catalogue Corporation, New York, New York.

The strands are grasped with the left hand, cut, figure 123, 5, and twisted into a hank, figure 123, 6, 7, which is moistened with wet finger tips and tucked into a test tube, figure 123, 8, 9. The test tube is packaged in a sterilizing wrapper, figure 123, 10, placed on its side in the sterilizer, and sterilized just as other textiles.

Fine suture material is easier to use when stiffened and lubricated. This is done by cutting the silk from the reel, figure 123, 5, and immersing it in white, washed beeswax, melted over an electric hot plate, figure 124, 11. The gross excess is removed with a forceps, figure 124, 12. The opposite end of the strand is dipped in wax and the excess is rubbed off with washed gauze, figure 124, 13. The strands are twisted into a hank and it is tucked into a test tube for sterilization. Because beeswax is hydroscopic, it adsorbs sufficient moisture (22%) to permit sterilization by saturated steam. Beeswax stiffens the suture material sufficiently to make it stand and throw easily. Waxed silk ties smoothly but three knots must be used on critical ligatures because knots in waxed thread slip readily. The waxing does not make the silk non-capillary, moisture-proof, or serum-proof nor does it protect the silk from adsorbing sufficient water to lose tensile strength as it does when wet, nor does it decrease capillarity at the suture-tissue interface, a factor which is constant whether stainless steel or untreated textile fibers are used as suture material.

A convenient technic for preparing fine suture material on No. 8 egg-eyed milliner's needles is shown in figure 125. The needles are threaded with sutures cut as detailed in figure 123, 4, taking care to leave one leg of the thread about 2 cm longer than the other. A piece of 7.5 cm gauze bandage, 22.5 cm long, is fanfolded, figure 125, 1 to 4, and the needles are in-

PREPARING SILK



tives, natural resins, or protein aggregates. These substances are known as binders. Other basic compounding materials include fillers, plasticizers, dyes, lubricants, and solvents. Various fillers may be added to binders to obtain qualities that the resin itself does not have, for example, high electrical, chemical, impact, or heat resistance. Typical fillers are wood flour, cotton fabric, graphite, asbestos, and mica. Plasticizers are added in some instances to increase flow properties for ease of molding, in others to increase impact strength. Plasticized resins lose some of their inherent tensile and compressive properties. Typical plasticizers are the sulfonamides, phthalyl glycolates, or triphenyl phosphates. Figure 122²³ lists the principal plastics encountered in hospitals. The resumption of civilian production will bring many new materials and many new plastic products to the hospital.

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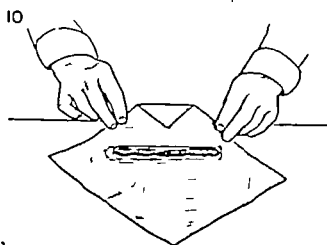
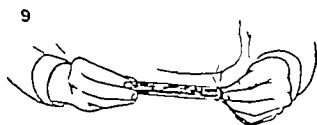
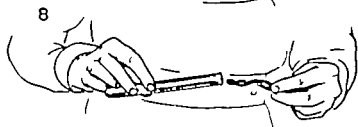
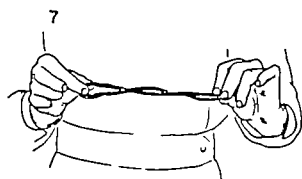
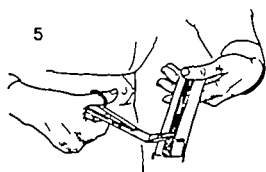
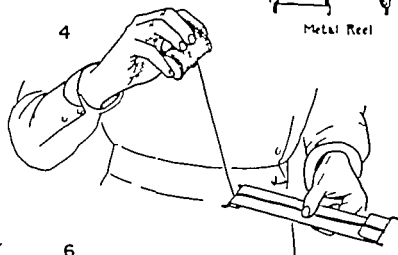
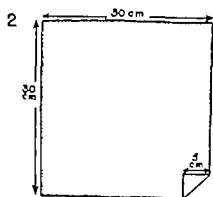
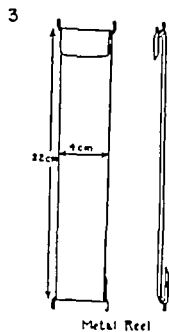
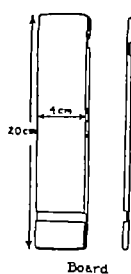
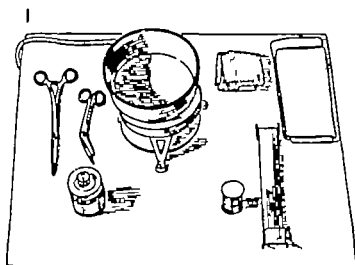
²³ *Plastics Catalogue*, 1945. *Plastics Catalogue Corporation*, New York, New York.

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PREPARING SILK



WAXING SILK

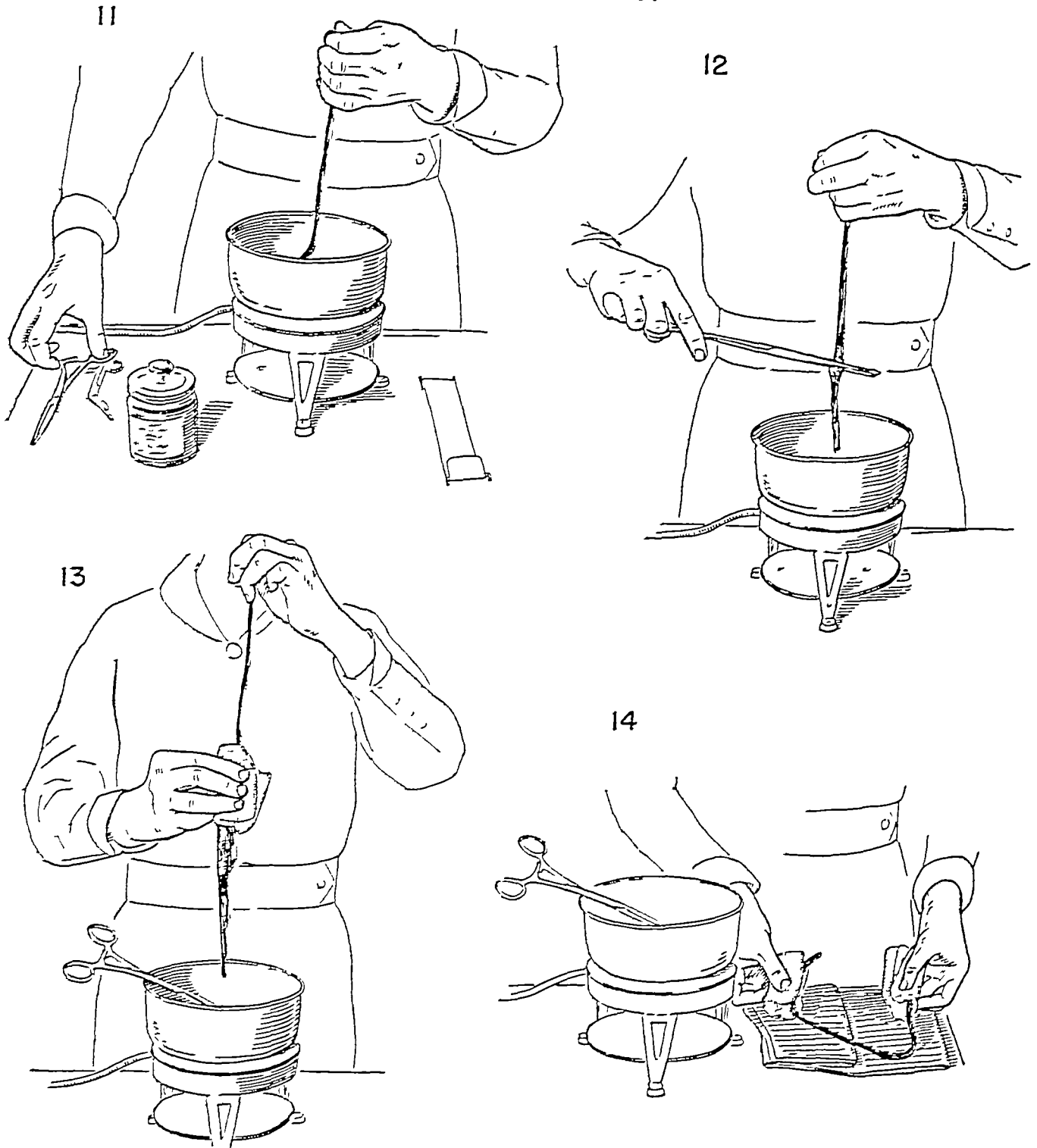


FIGURE 124

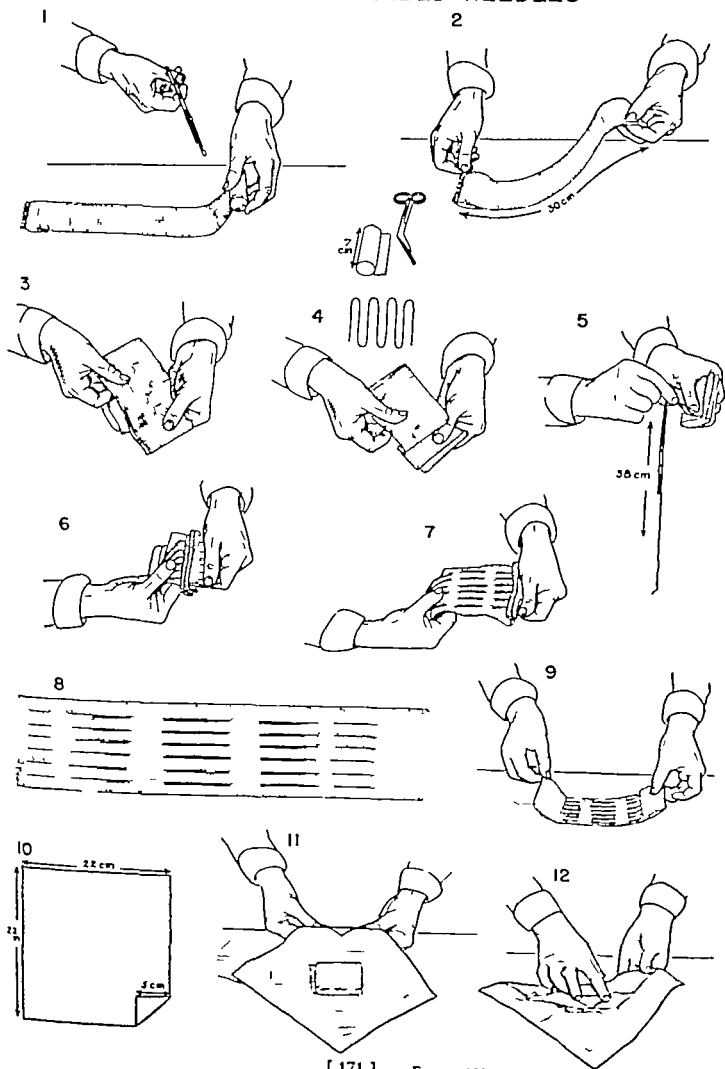
serted through it, figure 125, 5. The short fold and the needles are grasped tightly in the left hand, figure 125, 6. and the gauze is pulled out straight, basting the threads through the gauze. figure 125. 7. 8 The gauze is folded on itself from the ends

toward the center, figure 125, 9, and packaged for sterilization, figure 125, 10 to 12

STERILIZATION OF AMPOULES

Ampoules containing drugs which are frequently used on a sterile field can be

PACKAGING THREADED NEEDLES



sterilized in an alcoholic formaldehyde solution if care is taken to provide a cover which will keep the ampoules immersed, figure 18, 5, 6. Because such ampoules may be cracked and leak, it is desirable to color the solution with a dye so that if the solution is aspirated into an ampoule, the discoloration will signal the fact that the contents are unsuitable for use. Formulae for coloring germicides are given in Chapter III.

STERILIZATION OF BRUSHES

The technic for the sterilization of hand brushes is determined by the type of bristle of which the brush is made. The pale yellow vegetable fiber bristle will withstand sterilization by steam or sanitization by boiling but these bristles make a soft, ineffectual brush which is little better than using a rag. Animal bristle brushes, of so-called Chungking or hog bristle, can be sanitized in boiling water but deteriorate quickly. When exposed to saturated steam, the bristles are destroyed in one or two sterilizations because even at 56°C, hog bristles begin to split, wrinkle, and curl. Animal bristle brushes are therefore best disinfected by submersion in chemicals. They should be rinsed free of soap and stored in an aqueous germicide, either 1:1000 aqueous Zephiran or 1:400 aqueous iodine solution. Synthetic bristles, particularly nylon, withstand repeated sterilization with saturated steam without affecting their brushing characteristics. One experimental brush* withstood 297 trips through the steam sterilizer before signs of deterioration were noted. This type of brush can be sterilized along with textiles.

STERILIZATION OF UTENSILS

Basins and other utensils are advantageously sterilized by saturated steam be-

* No. 157, made by Prophylactic Company, Florence, Massachusetts

cause an assortment, figure 126, 1, can be packaged for easy handling and storage. Because the kits are dry when removed from the sterilizer, odd items of dry goods customarily used in the basins may be sterilized in them. The large basin serves as a nest for the array of smaller utensils. Three abdominal packs are placed in the saline basin, figure 126, 3, along with four straight sponges. Four straight sponges are placed in the suture basin, figure 126, 5. Six knotted sponges are put into each kidney basin, figure 126, 7, and the specimen basin tops the nest, figure 127, 8. It is imperative to arrange the utensils so that the package can be placed on its side in the sterilizer without trapping air in an upright vessel. Contrast figures 127, 8, and 127, 9. The kit is packaged in a double thickness muslin wrapper, figure 127, 10, which also serves as the sterile drape for the basin stand. The corners are turned back, figure 127, 12, to provide a tab for an unsterile nurse to open the package safely. Properly packaged and loaded kits can be sterilized with bundles of textiles by exposure to saturated steam at 121°C for thirty minutes.

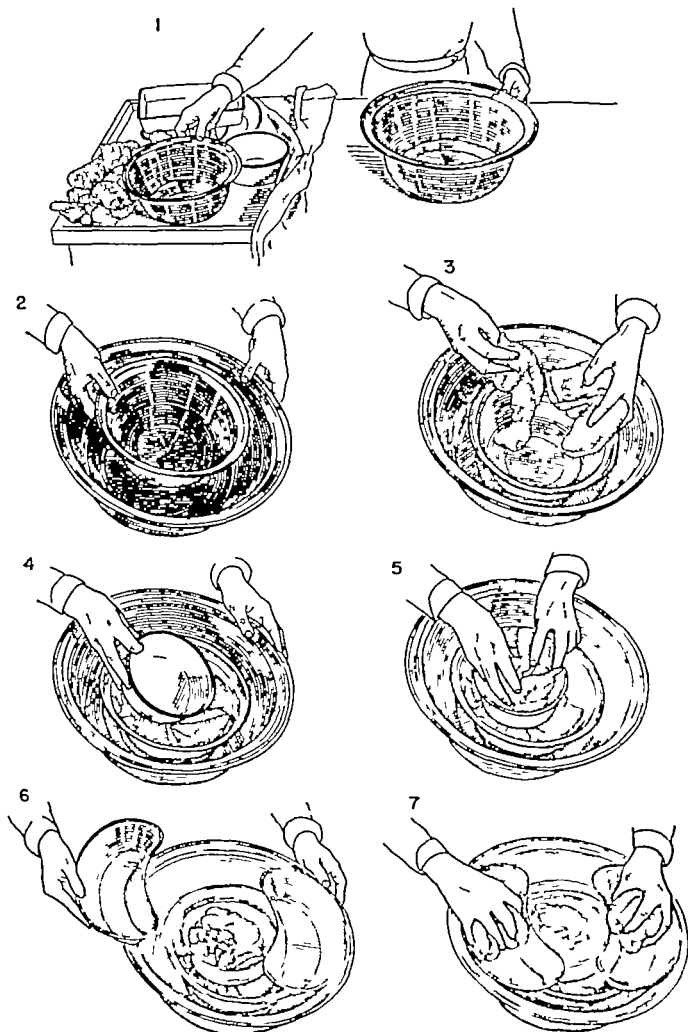
STERILIZATION OF NURSE'S KIT

The instruments used by the suture nurse are most conveniently assembled and sterilized together so that they are instantly available at operation. A kit containing the following list of instruments can be packed in an aluminum tray (anodized Wearever No. 243) as is shown in figure 128.

2 conical glasses	6 towel clips
1 blade for scratching the skin	1 large glass suction tip and two and one-half yards of rubber tubing
3 general needle holders	1 Asepto syringe and bulb
3 French needle holders	

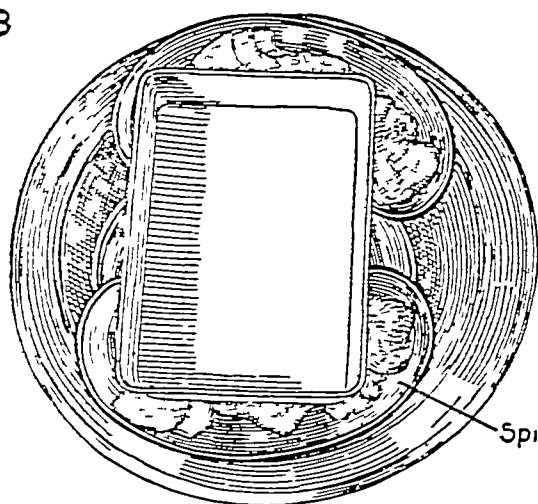
To insure sterilization of the inner surface of the rubber tubing and Asepto syringe bulbs, they are rinsed with water immediately before sterilization as described in

ASSEMBLING BASIN KIT



WRAPPING BASIN KIT

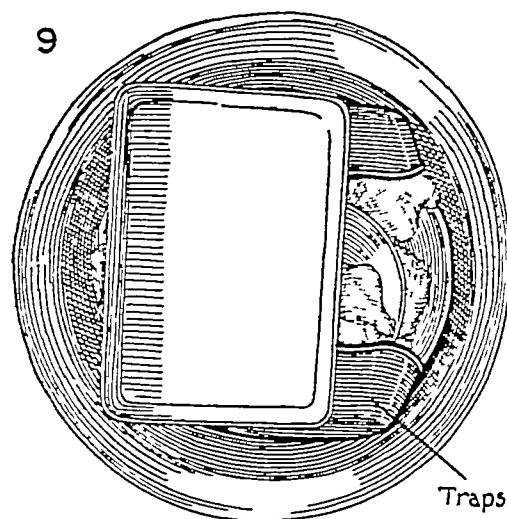
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Spills air

Correct

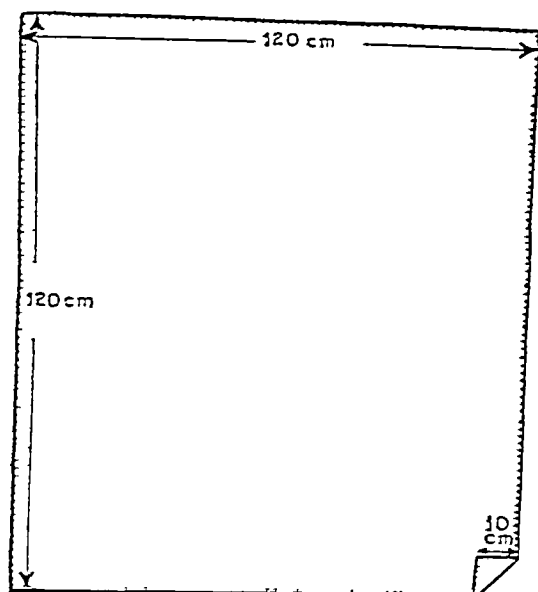
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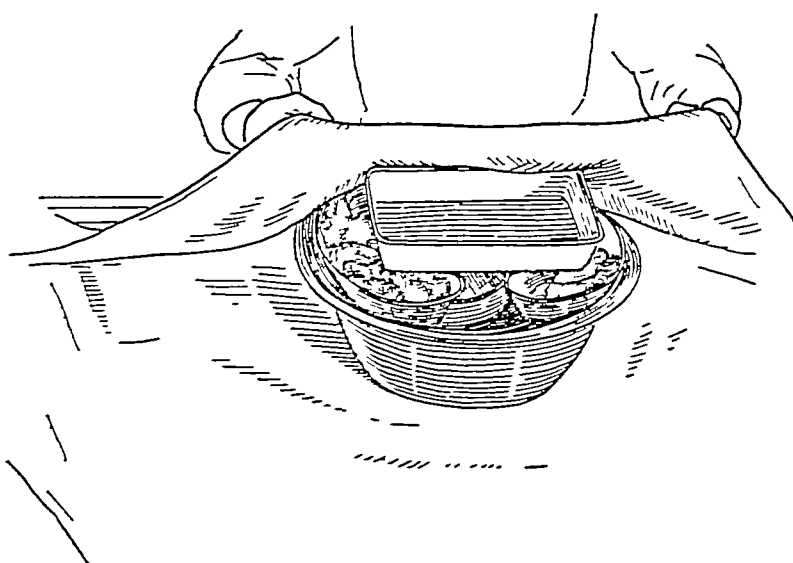
Traps air

Incorrect

10



11



12

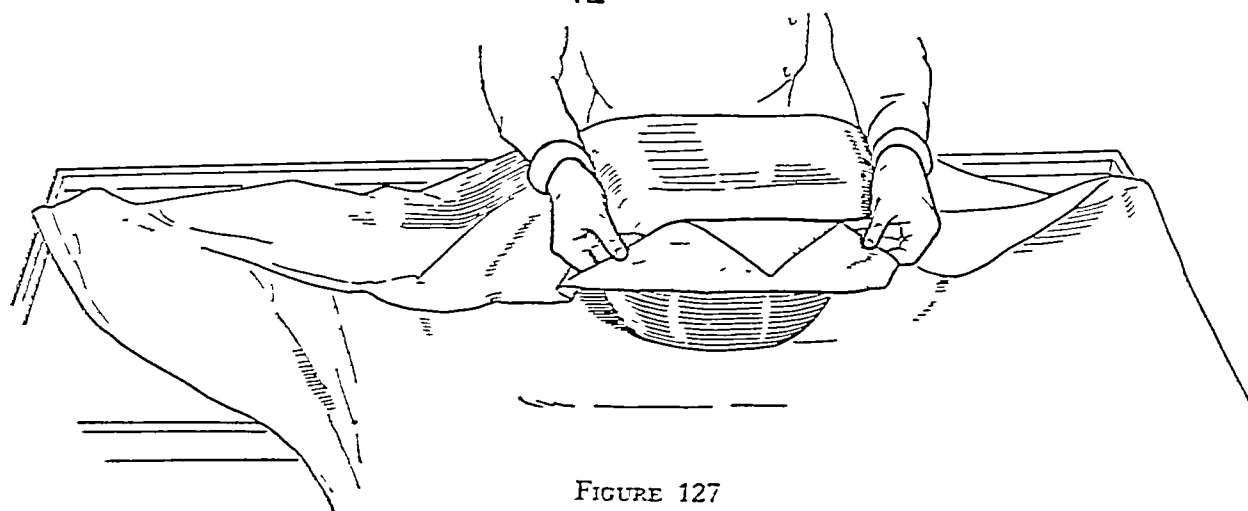


FIGURE 127

PACKAGING NURSE'S KIT

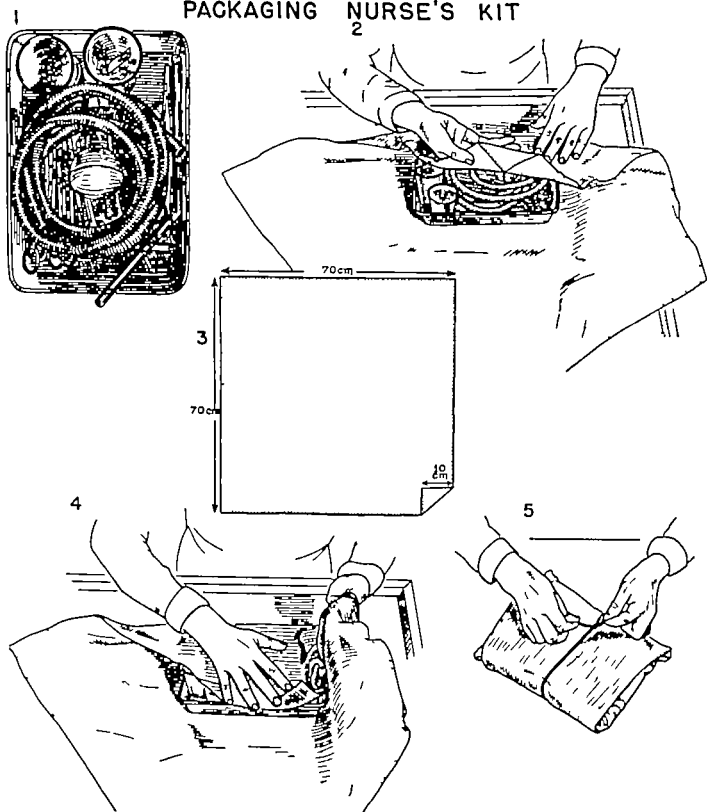


FIGURE 128

Chapter XVI. Nurses' kits are sterilized as are instruments because preheating is essential to prevent corrosion of the needle-holders.

A camera can be brought into the sterile field so that the surgeon can make a visual record of the operative procedure himself.³⁹ The unsterile camera is positioned on a metal frame in an everted sterile muslin bag

³⁹ INGRAHAM, F. D., and COBB, C. A., JR.: A Simple Method of Making Photographic Records under Sterile Conditions. *J. Neurosurgery* 4:293-297; 1947.

held by the scrub nurse. The sterile bag is rolled back over the camera and closed by a draw string, completely enveloping the camera. The metal frame supports the camera behind a Pyrex window through which the pictures are made. The camera is operated by inserting the fingers into tiny pocket stitched in the bag at appropriate points. The author regrets that this contribution escaped his note until too late to have illustrations made.

CHAPTER XII

DISINFECTION OF THE SKIN

As we may constantly approach a limit in geometry but never reach it, so in surgery we can minimize, but never permanently eliminate, bacteria in the field. Beware of the operator who says he never has a clean-wound infection.

— ALLEN O. WHIPPLE, 1933¹

An obvious source of contamination of surgical wounds is the skin of the patient and that of the eight or ten hands which contact the wound either directly or indirectly at operation. It has been estimated that a minimum of 10,000 organisms are present per square centimeter of normal skin.² Three methods have been utilized to reduce this inevitable contamination to a minimum. The classic technic is to apply germicides with the hope that a relatively sterile field will result. The danger of injuring tissue contraindicates the use of germicides sufficiently strong to be effective in practicable periods and human impatience militates against germicides that are kindly to tissues but slow in action.

More recently, mechanical cleansing has been rediscovered as the most important factor in removing organisms from the skin. The result has been emphasis on making skin surgically clean by actually scrubbing off the organisms which adhere to the surface or grow in the superficial desquamating epithelium.

The newest technic attempts to exclude the skin from the wound by coating it with an adherent protective film which acts as an impenetrable barrier between the sterile field and the skin.^{3,4,5} Germicides can be added to such films to gradually disinfect the underlying skin. A successful technic depends upon the deposition of an adherent, bactericidal, elastic, transparent film that is impermeable to bacteria and can be incised cleanly and easily. Films that crack and flake apart are useless and fill the wound with foreign bodies. A suitable formula is⁷

vinylite resin, AYAF	25 gr
acetone	100 cc.
nitrocellulose	1.32 gr
phenol	1.00 gr

As originally described, the technic calls for the usual preoperative shave. At operation, the field is vigorously and thoroughly cleansed and defatted with ether. Nine separate scrubblings are used. The vinylite mixture is then applied with a soft rubber applicator. Sterile drapes may be applied

¹ WHIPPLE, A. O. The Use of Silk in the Repair of Clean Wounds, *Am. Surg.*, 98:662, 1933.

² HARRISFIELD, J. W. Bacterial Contamination of Wounds from the Air from the Skin of the Operator and from the Skin of the Patient, *Surg., Gyn. & Obs.*, 73:72-78, 1941.

³ HARRISFIELD, W. S. Ligature and Suture Material, the Employment of Fine Silk in Preference to Catgut and the Advantage of Transfixion of Tissues and Vessels in Control of Hemorrhage, Also an Account of the Introduction of Gloves, Gutta-percha Tissue, and Silver Foil, *J.A.M.A.*, 60:1119-1126 1913.

over the undried resin which then sticks them directly to the skin. A useful modification consists in cleansing the skin with a synthetic detergent prior to the application of the film. It is interesting to note that bichloride of mercury has been popular because it was believed to have strong germicidal properties. Recent knowledge reveals that it is but a bacteriostatic agent and that its effectiveness is due to a protective film which forms on the surface of the skin to isolate the wound.² Thus, unwittingly, surgeons have used empirically a technic which may be the ultimate solution of the problem of disinfecting the skin.

The normal bacterial flora of the skin varies with anatomic location as well as with individuals.³ In protected regions, such as in creases, the bacteria may be numerous, while on smooth exposed surfaces they may be few. Every skin is inhabited by a relatively stable basic population of saprophytes, characteristic of the individual. The composition of these resident flora may be modified by contaminating bacteria which adapt themselves to the skin and take up residence indefinitely. A classic example is cited by a surgeon who had active charge

of a ward where patients with infected gunshot and shell wounds were cared for. Although he dressed the wounds with unusual care with his ungloved hands, he was startled to find that the resident flora of his hands included a large proportion of pathogenic organisms after several weeks' work on the ward — "chiefly staphylococcus aureus, many of them hemolytic but also streptococci of various sorts, B coli, and B pyocyaneus."¹⁰ In spite of frequent washing and daily disinfection of the hands, these pathogenic organisms persisted for many weeks after he ceased work on the septic ward. This experience in applied bacteriology confirms the age-old dictum that the surgeon must avoid contamination of his hands with pus and other sources of dangerous organisms. Accidental contamination must be removed completely to avoid the danger of spreading the infection not only to immediate contacts but indefinitely by hands which have become chronic carriers of pathogenic bacteria. Prompt removal is of paramount importance because there is no certain method of eliminating pathogenic bacteria which have become residents of the skin. Similarly, the resident flora of the patient's skin, which is frequently contaminated by discharge from wounds, may include pathogenic organisms which may contaminate incisions made through it.

The transient flora of the skin thrives on the surface rather than in the deeper layers. It either adheres to or is adsorbed to the skin surface and is best removed by friction. On exposed surfaces, bacteria are rubbed off more rapidly than their normal rate of increase. On protected surfaces, in creases and folds, the bacteria accumulate because

¹KUTTNER, H.: Transactions (in part) of the German Surgical Society. Fortieth Congress held April 19-22, 1911. *General Surgery, Pathology and Therapy 1 Disinfection of the Hands and Site of Operation*. Translated from *Beilage zum Zentralblatt für Chirurgie*, No. 29, 1911, by Oswald Joerg, Max Lederer and James T. Tilcher.

²MCDONALD, E.: A Skin Varnish and Substitute for Rubber Gloves, *M. Rec. N. Y.*, 25:524, 1914.

³ECKER, A. D.: New Skin Varnish for Maintaining Sterility of Operative Field, *Surgery*, 12:631-634, 1942.

⁴DEBATEY, M., GILES, E. J. and HONOLD, E.: The Protection of the Operative Field with an Impermeable Adhesive Skin Coating — A Preliminary Report, *Surg., Gyn. & Ob.*, 74:490, 1942.

⁵PRICE, P. B.: New Studies in Surgical Bacteriology and Surgical Technique with Special Reference to Disinfection of Skin. *J.A.M.A.*, 111:1292-1296, November 26, 1932.

⁶FURBER GEB: Zur Desinfektion der Hände des Arztes, *Deutsch. med. Wochenschr.*, xiv:225-227, 1888.

¹⁰PRICE, P. B.: Bacteriology of Normal Skin, New Quantitative Test Applied to Study of Bacterial Flora and Disinfectant Action of Mechanical Cleansing, *J. Infect. Dis.*, 63:301-312, 1938.

REESTABLISHMENT OF BACTERIAL FLORA

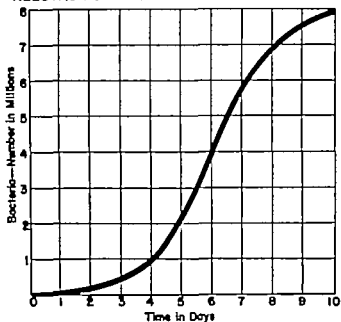


FIGURE 129

Price¹⁰

DISINFECTION BY MECHANICAL CLEANSING

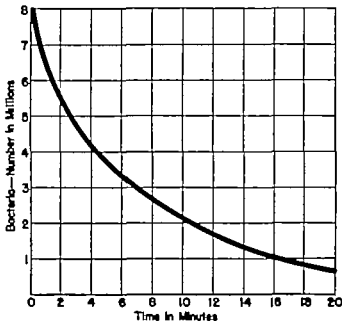


FIGURE 130

Price¹⁰

the forces tending to decrease the population are ineffectual. The anatomic structures in the deeper layers of the skin harbor the resident organisms. Sweat, as it comes from the pores, has been demonstrated to be sterile.^{10 11 12} Bacteria are located in hair follicles and ducts of sebaceous glands whence they cannot be recovered mechanically and are inaccessible to commonly used germicides. These organisms rise to the surface during an operation and constitute a source of wound contamination.

The transient organisms which are found on the skin reflect the daily contacts of the individual because they accumulate on the exposed surfaces along with soil. These bacteria may lie free on the skin or may be held by grease or fats. They collect in the subungual spaces and in the creases about the knuckles. Most bacteria do not adapt themselves to life on the dry skin and die out. Others are facultative and may persist and become permanent residents. Transient bac-

¹⁰ HARRINGTON, C. Some Studies in Asepsis, *Ann. Surg.*, 40:475, 1904.

¹¹ LOVELL, D. L. Skin Bacteria. Their Location with Reference to Skin Sterilization, *Surg. Gyn. & Obs.* 80:174, 1945.

teria can be removed from the skin easily by washing or rubbing the skin.

When the bacterial flora on the skin has been reduced to a minimum, re-establishment occurs slowly, being complete after a week, figure 129. Skin that is disinfected daily, therefore, consistently shows a lower bacterial flora than that which is disinfected only occasionally. Under rubber gloves, the proliferation of bacteria is accelerated. One report states that hands having a bacterial flora of 3,000,000 were found to have a flora of 25,900,000 after gloves had been worn two hours and forty minutes. The bacterial flora can be reduced by mechanically cleansing the skin as shown in figure 130. Scrubbing reduces the number of bacteria at a constant logarithmic rate. There is a reduction of one half each six minutes or two thirds each ten minutes of scrubbing. Theoretically, it would require two and one half hours of continuous scrubbing to sterilize the skin. Mechanical cleansing is effective because of the friction produced at the skin surface which rubs bacteria off. The more friction, the more rapid is the rate at which organisms are removed. A stiff

brush and vigorous scrubbing hasten the disinfection as compared with a soft brush and languid scrubbing. Tap water is just as effective as sterile water because the organisms suspended in the water are not implanted on the skin. Routine scrubbing is effective in removing the organisms from under the fingernails provided the nails are trimmed short (1 mm or less). After seven minutes of scrubbing, the subungual spaces were found to contain relatively few viable organisms.¹⁰ The ease with which transient organisms are removed contrasts with the difficulty in removing residents. The former are held in place chiefly by grease, fats, and superficial soil and are removed along with the dirt in fats emulsified by soap and warm water. The majority of the transient organisms are removed within the first two minutes of scrubbing.

Wet skin cannot be contaminated readily because organisms picked up from clothing, faucets, or even the floor are quickly washed off. Hence, the traditional care used while scrubbing to avoid such contacts is misplaced.

Preoperative preparation of the skin attempts to remove the dirt, fats, and transient organisms with the least inconvenience possible. The nails are trimmed short and the subungual spaces are scraped with a sharp edged metal scraper to remove all visible soil. Hands and arms are then scrubbed with warm tap water, using a soap which emulsifies well and builds up an abundant lather. Coconut oil or castor oil soaps have been demonstrated to have germicidal action in concentrations as low as 0.5% following an exposure of two and one-half minutes.¹³ A stiff lather of coconut oil soap contains 15% soap and is effective

against pyogenic organisms other than the staphylococcus.

A new synthetic phenol compound, 2,2'-dihydroxy-3,5,6-3',5'6-hexachloro-diphenyl-methane, has been described as being a remarkable disinfectant for the skin.¹⁴ Two per cent of the compound, known commercially as "G-11"¹⁵ is added to liquid soap for use in scrubbing the skin. Two minutes' scrubbing with the mixture lowers the resident count more than twenty minutes' scrubbing with ordinary toilet soap. A low bacterial count can be maintained continually by the daily use of G-11. No skin sensitivity to G-11 has been demonstrable, but those who react to soaps cannot use the mixture.

Ideally, the disinfection of the skin of the hands should be based upon a habitual anatomic scrub which covers every area of the skin rather than upon an arbitrary period of scrubbing, because the effectiveness of individual scrubs varies tremendously. Hence, if the habit is established of scrubbing every area of the skin successively on both hands, the most reliable scrub is developed on a basis of scrubbing each area a certain number of strokes. Thus, if every area is scrubbed with three strokes of the brush before the succeeding area is scrubbed, all the skin of both hands and arms is covered with the minimum of three strokes. If this coverage is repeated ten times over, the optimum removal of bacteria is accomplished, figure 131, one stroke of a hand brush equalling ten of those described in the graph. This technic has the advantage that the easy-going scrubber does not escape disinfection while scrubbing for the same arbitrary period as the

¹³ WALKER, J. E. The Germicidal Properties of Chemically Pure Soap, *J Infect Dis*, 35:557, 1924. The Germicidal Properties of Soap, *J Infect Dis*, 37:181, 1925, 38:127, 1926.

¹⁴ TRAUB, E. F., NEWHALL, C. A., FULLER, J. R. Value of New Compound (Dihydroxyhexachlorodiphenyl Methane) Used in Soap to Reduce Bacterial Flora of Human Skin, *Surg, Gyn & Ob*, 79:205-216, 1944.

¹⁵ Givaudan-Delawanna, Inc., Delawanna, New Jersey.

SCRUBBING REMOVES BACTERIA

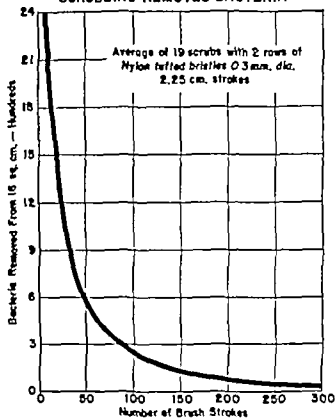


FIGURE 131

vigorous scrubber. A diligent person can develop an anatomic scrub that yields optimum results in seven minutes. Those who scrub their hands frequently and who protect their hands against contamination can safely cut such a scrub to five complete cycles because there is little opportunity for the re-establishment of a prolific flora, whereas those who have been gardening or have otherwise grossly soiled their hands should persist for fifteen cycles.

Any method of scrubbing the hands is no more effective than the thoroughness with which every surface of the skin is mechanically cleansed. A habitual scrub must be developed to eliminate blind areas. A simple way of teaching a proper technic is to rub a 10% mixture of lampblack in salad oil thoroughly into the hands and arms.¹⁶ The pupil should then be blindfolded and pro-

¹⁶ LEIBENTHAL, H. and ZIEGLER, J. A Study of the Disinfection of Hands, *Am. Surg.*, 83:831-836, 1926.

DISINFECTING EFFECT OF ALCOHOL ON SKIN

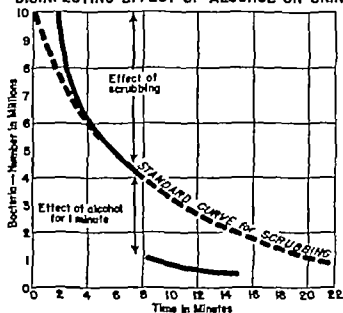


FIGURE 132

Price¹⁷

vided with soap, a brush, and running water and instructed to scrub until he believes his hands are clean. It is amazing to see how even experienced members of the operating room personnel leave black areas on the ulnar side of the thumb, between the fingers, on the ulnar side of the arms and often one half to two thirds of the right hand. Repeated bouts of scrubbing off lampblack are necessary to teach some individuals the habit of scrubbing all the skin.

The mechanical scrub removes, along with the transients, about one half the resident flora. Chemical disinfectants must be relied upon to destroy more of the organisms remaining on the clean, dry, fat free skin. This can be done by rubbing the skin with suitable germicides so that ultimately the original flora is reduced to something less than 2%.¹⁷

Ethyl alcohol, 70% by weight, is an effective germicide for the skin. Rubbing it on the skin for one minute is as effective as twelve minutes of scrubbing, figure 132. Because slight variations from the 70% con-

¹⁷ PRICE, P. B. Ethyl Alcohol as a Germicide, *Arch. Surg.*, 58:528-542, 1939.

USE OF ARM SOAK

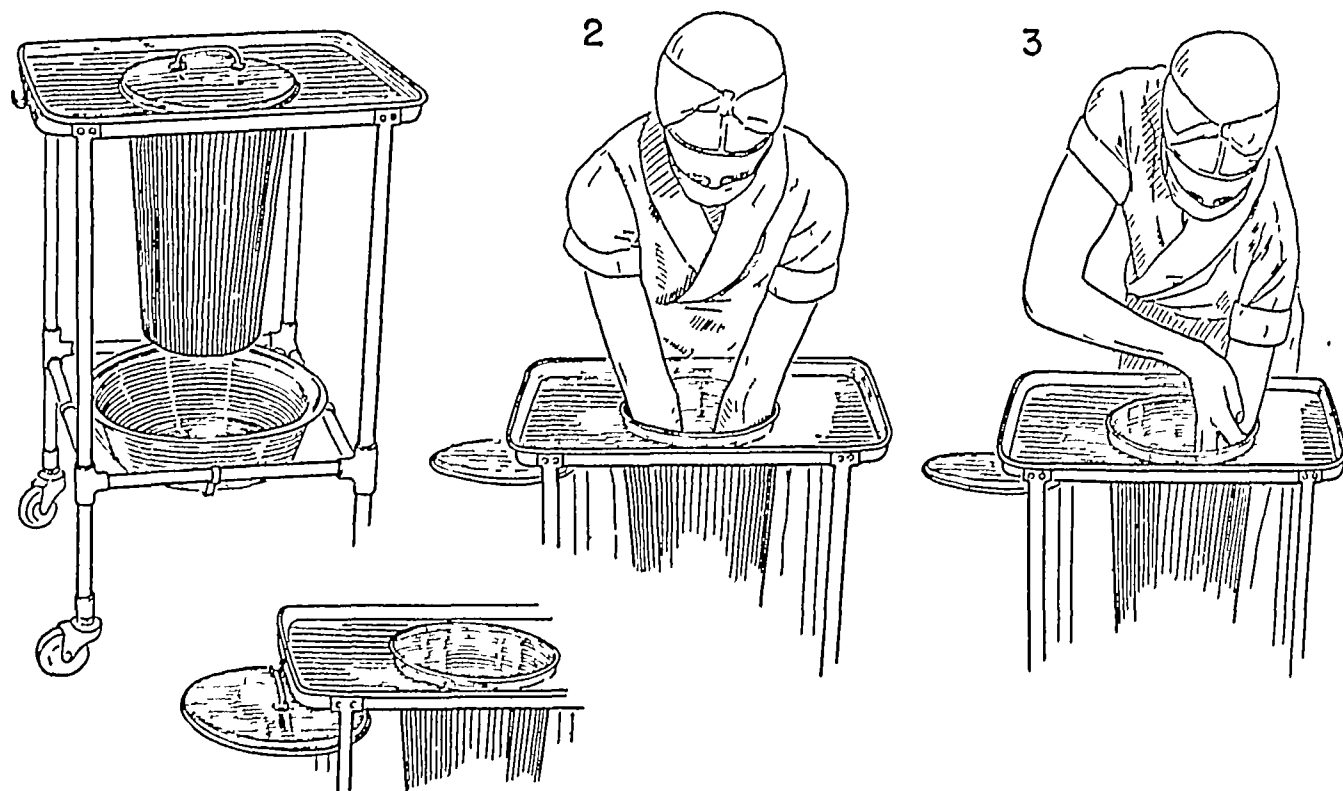


FIGURE 133

centration of alcohol result in marked decrease of bactericidal power, it is important to dry the skin thoroughly on a sterile towel to avoid dilution of the alcohol which is to be used subsequently. The skin is then rinsed briefly in 95% alcohol to dehydrate it further and the arms and hands are next rubbed with a gauze sponge or wash cloth while submerged in 70% alcohol for three minutes.

Another germicidal mixture which is advantageous for the disinfection of the skin consists of a mixture of ethyl and propyl alcohol (see Chapter III). Immersion in this solution for one minute is equivalent to eleven minutes of scrubbing. Friction while immersed increases the germicidal action.

The application of Semmelweis's paste is so effective that four minutes of rubbing the paste into the skin results in a reduction of bacteria equivalent to twenty minutes of scrubbing.

Forty per cent propyl alcohol, 1:1000 aqueous Zephiran, or 0.5% aqueous iodine are reliable when rubbed into the skin for two minutes. An arm soak such as is illustrated in figure 133 is convenient because it provides enough room so that the skin can be rubbed while submerged, and it also catches any solution that may be splashed out.

Those who operate only occasionally or who prefer to do minor surgery without wearing gloves can avail themselves of the technic which uses bichloride of mercury, 1:1000 aqueous solution, or an aqueous solution of potassium mercuric iodide, 1:500, to precipitate an impervious film on the skin which is sterile but under which existing organisms proliferate so rapidly that the population doubles every fifty minutes. If this technic is used frequently, the nails discolor and some individuals develop contact dermatitis or have difficulty with the nails splitting and cracking.

An interesting study from the battle front describes the use of 1 1000 aqueous Zephiran in place of soap and water for scrubbing the hands because of the higher cost and bulk of the soap and the scarcity of water. The nails were cleaned, the hands and forearms scrubbed vigorously in Zephiran solution for three minutes and then immersed for three minutes in a basin containing 1 1000 aqueous Zephiran solution¹⁸

The preparation of the hands and arms between operations is a simple, straight forward problem of destroying the bacteria which have multiplied under the gloves. This can be done effectively by reapplication of the original bactericide used for disinfecting the skin. The preoperative scrub need not be repeated because it contributes nothing to bacteriologic safety.

DISINFECTION OF CONTAMINATED HANDS

Occasionally, the surgeon's hands are unavoidably contaminated with pus or other infectious material or it is imperative that an infectious area be examined digitally when the protection of a rubber glove is not available. The ideal technic for preventing contamination of the skin with pathogenic organisms involves the preliminary cleansing of the hands so that the skin is free from grease and soil, which aid transient organisms in adhering to it. Contamination should be washed from the skin without delay with soap and running water. Brushing should be avoided because the bristles are likely to implant the organisms into the sebaceous glands or hair follicles. The hands should then be dried on an individual towel and disinfected with one of the germicides described above. A convenient technic is to moisten them thoroughly with a few cc. of

70% alcohol and let them dry slowly by evaporation.

In the laboratory, where more virulent and heavier contamination of the hands occurs, the safest technic is to rinse off the gross contamination under running water and to rub lime paste into the skin for two minutes.

DISINFECTION OF THE OPERATIVE SITE

The type of preoperative preparation of the skin depends upon the anatomic location and the preoperative diagnosis. On smooth areas of the skin, the routine mechanical scrub can be applied but on complicated surfaces, such as the scrotum, or in disinfecting skin over superficial malignancy, an atraumatic technic is preferable.

Mechanical cleansing of flat, smooth areas of skin can be accomplished readily by working up a lather of coconut oil soap with a soft sponge and maintaining it for two minutes. The latter should then be shaved off with a sharp, straight-edged razor. If this procedure is performed by a skilled individual, the razor removes most of the desquamating epithelium and surface bacteria quickly and easily. The skin is then washed with warm tap water and dried. No dressings need be applied because they are bacteriologically useless and needlessly increase the apprehension of the patient. This stage of the preoperative preparation is sufficiently important to warrant its being entrusted only to experienced personnel. It is not time-consuming or inconvenient for some skilled member of the operating room personnel to prepare the skin of the operative field. Certainly no one who cannot strop a razor to a keen edge should be entrusted with the procedure because the all too prevalent dull hoe technic of tearing off hair removes but few of the keratinized epithelial cells.

¹⁸ SCHUMAKER, H. B. and BETHEA, W. R. Some Studies with Zephiran with Particular Reference to Its Use in Time of War. *Surgery* 14:931-945 1943.

Ideally, shaving should be done at least twelve hours preoperatively whenever possible, because there is evidence that the skin has natural powers of disinfection which are markedly decreased by shaving but which recover in a period of from four to six hours¹⁹⁻²⁶

One aspect of the preoperative preparation of the skin which is entirely forgotten in many hospitals is the avoidance of contamination of the healthy skin of the candidate for surgery with pathogenic organisms from other patients. Bathing in unclean tubs in which patients with draining wounds have been bathed or using brushes and razors which have not been sterilized or passing out bedding promiscuously are some of the more obvious ways of contaminating the operative field preoperatively with organisms which may cause havoc if they are not destroyed²⁷

In the operating room, the skin is disinfected just before the drapes are applied.

¹⁹ HARDY, A. V., HUDSON, M., JORDAN, C. F. The Skin as a Portal of Entry in Br. Melitensis Infections, *J. Infect. Dis.*, 45:271, 1929

²⁰ PIJOAN, M., and WHEELER, S. Use of Extravasating Dye as Measure of Skin Permeability to Bacterial Invasion, *Arch. Surg.*, 34:591-598, 1937

²¹ BURTONSHAW, J. M. L. Mechanism of Self-disinfection of Human Skin and Its Appendages, *Am. J. Hyg.*, 42:184-210, 1942

²² ARNOLD, L., GUSTAFSON, C. J., HULL, G., MONTGOMERY, B. E. and SINGER, C. Self-disinfecting Power of Skin as Defense against Microbic Invasion, *Am. J. Hyg.*, 11:345-361, 1930

²³ ARNOLD, L. and BART, A.: Self-disinfecting Power of Skin, *Am. J. Hyg.*, 19:217-228, 1934

²⁴ CORNBLEET, T., MONTGOMERY, B. E. Self-sterilization Powers of Skin, *Arch. Derm. & Syph.*, 23:908-919, 1931.

²⁵ CORNBLEET, T. Self-sterilization Powers of Skin, Body Folds, *Arch. Derm. & Syph.*, 25:1058-1059, 1932

²⁶ CORNBLEET, T. Self-sterilizing Powers of Skin, Carbohydrate Metabolism, *Arch. Derm. & Syph.*, 26:463-465, 1932

²⁷ MILES, A. A., SCHWABACHER, H., CUNLIFFE, A. C., ROSS, J. P., SPOONER, E. T. C., PILCHER, R. S. and WRIGHT, J.: Hospital Infection of War Wounds, *Brit. M. J.*, 2:655, December, 1940

There are three essentials for chemical disinfection of the skin

1 There must be an adequate period of exposure to the germicide. No germicide is instantaneous in its action and time must be allotted for the germicide to act

2 The germicide must be maintained at its most effective concentration on the skin. As germicides dry, their power to destroy bacteria is lost

3. Friction enhances germicidal power because it aids the germicide in penetrating to the organisms

The ideal germicide should have detergent properties as well as bactericidal power. A good skin preparation based upon a pair of germicides with contrasting detergent powers is that of scrubbing the skin with sponges moistened alternately with 1:1000 aqueous Zephiran and 70% alcohol, figure 165. Another involves rubbing the skin with sponges moistened with 70% ethyl alcohol or ethyl-propyl-alcohol solution

A technic which appeals to many because it demarcates the disinfected area is that used by the American Red Cross Blood Donor Service. The fact that at the Boston Center 60,658 consecutive pints of blood were taken without a single contaminated bottle speaks well for its efficiency. The skin is scrubbed vigorously for a minute with 5% coconut oil soap. Most of the lather is removed with the sponge and U.S.P. solution of iodine is applied and rubbed into the skin for a minute. It is important to keep the iodine moist. The iodine is then removed by swabbing the skin with 70% alcohol

An atraumatic preoperative skin preparation is desirable wherever superficial malignancy contraindicates trauma or in anatomic areas such as the scrotum, the axilla, the hands, and the feet where anatomic considerations make mechanical cleansing unreliable. A good technic is to develop a

stuff lather with a soft sponge and hot water and to shave the lather off with a sharp razor while the skin is gently tensed so that it presents a flat, smooth surface to the razor. The germicide is handicapped in such areas because friction is not effective, hence, prolonged exposure is necessary except for the most potent of them — lime paste — which can be applied for four minutes as a thin cream on the operating table and kept moist either by replenishing it at intervals or by adding saline solution to the cream. Other suitable technics are to apply a wet dressing to the area involved for thirty minutes preoperatively. Aqueous Zephiran, 1:1000, or 0.1% aqueous iodine are suitable germicides for this purpose. When the hands or feet are to be disinfected, the best procedure is to furnish the patient with a brush and soap and teach him how to scrub the skin of his own hands and feet thoroughly. The patient is then asked to submerge the extremity in a solution of the germicide, or a rubber glove full of the germicide is put on and left in place until the patient comes to the operating room. In the operating room, the glove or dressing is removed and the skin is gently swabbed with 1:1000 aqueous Zephiran, if Zephiran is used in the wet dressing, or U.S.P. solution of iodine, if iodine is used in the wet dressing.

DISINFECTION OF SKIN THAT DOES NOT TOLERATE SOAP

Those who suffer from contact dermatitis due to soap can cleanse their skin by using synthetic detergents. A convenient one for routine use is an emulsion containing sodium p-ter-octyl phenoxyethoxyethoxyethyl ether sulfonate, lanolin cholesterol, and petrolatum.²⁸ It is commercially available under the trade name 'pHisoderm.'

²⁸ GUILD, B. T. Skin Detergents and Experience with an Ether Sulfonate Compound, *Arch. Dermat. & Syph.*, 51:391 1945.

An aqueous solution of Zephiran is compatible with the use of this detergent emulsion and seldom provokes a skin reaction.

The disinfecting action of pHisoderm fortified with 3% G-11 is so rapid that a two minutes' preoperative scrub is bacteriologically feasible.²⁹⁻³⁰ The use of this mixture provides optimum disinfection in areas where an atraumatic technic is desirable. It is good for preoperative preparation of the perineum and vagina. Means for economic dispensing currently prevent its widespread adaptation.

DISINFECTION OF WOUNDS

The disinfection of wounds and the skin surrounding them is frequently a subject for discussion. Three principles are important for wound healing:

1. The surrounding skin must be disinfected thoroughly.

2. All the dirt and devitalized tissue which are potential culture media for organisms must be removed from the wound. Destruction of bacteria in the wound itself is relatively unimportant, provided good hemostasis is attained and every portion of the wound presents viable tissue to combat the bacteria which must inevitably be left in the tissues.

3. Dangerous organisms must be excluded from the wound. There is evidence that many septic wounds result from the careless introduction of organisms into the wound by hospital personnel, either as a result of spitting into the wound while talking over it or by probing the wound with unsterile fingers or instruments.³¹⁻³²

Because the skin surrounding traumatic

²⁹ HUFNAGEL, C. H., HOWARD, R. and WALTER, C. W. An In Vivo Method for the Evaluation of Skin Antiseptics. In press, *Surgery* 1947.

³⁰ CHEEHOE, T. C., GRAHAM, M. J. and WALTER, C. W. An In Vivo Study of the Reduction of Skin Bacteria Employing a Detergent Containing G-11. In press, 1947.

THE MOST EFFICIENT OF 100 DETERGENTS AND DETERGENT MIXTURES TESTED

COMMERCIAL NAME	PROPORTIONS USED	CHEMICAL NATURE	ACTION	PHYSICAL NATURE OF MIXTURE
Sulfate Atlas-G 772S (Atlas Powder Co)	9 parts 1 part	Sulfonated petroleum Sorbitan laurate	Penetrant and Detergent Emulsifier	Clear orange-yellow oil Soluble in 3% NaCl
Sulfate (Glyco Products Co) Aerosol OT 25% (Am. Cyanamid Co)	11 parts 1 part	Sulfonated petroleum Di-octyl sodium sulfosuccinate	Penetrant and Detergent Detergent	Clear orange-yellow oil Soluble in 3% NaCl
Sulfate Orvus (Procter and Gamble Co)	19 parts 1 part	Sulfonated petroleum A fatty alcohol sulfate	Penetrant and Detergent Detergent	Clear orange-yellow oil Soluble in 3% NaCl
Sulfate Tergitol-4 (Carbon and Carbide Co)	49 parts 1 part	Sulfonated petroleum Higher secondary alkyl sodium sulfonate	Penetrant and Detergent Detergent	Clear yellow oil Soluble in 3% NaCl
Sulfate Oil Turkey Red (Eimer and Amend) Aerosol OT 25% aq	6 parts 5 parts 1 part	Sulfonated petroleum Sulfonated castor oil Di-octyl sodium sulfosuccinate	Penetrant and Detergent Penetrant and Detergent Detergent	Clear orange-yellow oil Soluble in 3% NaCl
Oil Turkey Red Aerosol OT 25% aq	11 parts 1 part	Sulfonated petroleum Di-octyl sodium sulfosuccinate	Penetrant and Detergent Detergent	Thick, orange-yellow oil Soluble in 3% NaCl

Rosenberg²²

wounds is often soiled with street dirt or grease and grime, it is advantageous to disinfect the skin and cleanse it simultaneously. Lime paste is an ideal agent for the purpose. A clean convenient method is outlined in figure 186.

The preoperative cleansing of burns and traumatized hands presents a problem in removing greasy grime of the most tenacious sort. Synthetic detergents are admirably suited to the purpose because they remove grime quickly with the minimal trauma necessary to swab or squirt them on the dirty area. Once the grime is impregnated with the detergent and "solubilized," it can be flushed away with clear water.

Synthetic detergents are characterized by having water-attracting (hydrophilic) and water-repelling (hydrophobic) groups at opposite ends of the molecule. When dispersed over a substance insoluble in water, whether particulate or homogenous, the hydrophobic groups orient themselves about the insoluble matter, leaving the hydrophilic groups presenting at the periphery.

²¹ KANAVEL, ALLEN B. *Infections of the Hand: A Guide to the Surgical Treatment of Acute and Chronic Suppurative Processes in the Fingers, Hand and Forearm*. Philadelphia: Lea and Febiger, 1933.

Oriented thus, the group has solubilized the insoluble matter so that it can be wet and removed by water. Suitable nonirritating, nontoxic mixtures for use as skin detergents are listed above.²²

The umbilicus deserves particular mention because it is difficult to disinfect without using a specific technic. Gross mechanical cleanliness is difficult to attain in many patients because of the greasiness of the accumulated detritus. Once the gross dirt has been removed, much progress can be made by applying one of the synthetic detergents. Repeated applications of pHisoderm containing 3% G-11 over the course of several hours will result in surgical cleanliness of the area.

The conjunctival sac and the oral cavity can be disinfected by the use of 1:1000 aqueous Zephiran. Several drops can be instilled in the conjunctival sac without causing symptoms or injection.²³ The mouth can be scrubbed with a sponge moistened with Zephiran.

²² ROSENBERG, N. *The Use of Detergents in the Cleansing and Local Treatment of Burns*, *Surgery*, 13: 385-393, 1943.

²³ WALTER, C. W. *The Use of a Mixture of Coconut Oil Derivatives as a Bactericide in the Operating Room*, *Surg., Gyn. & Ob.*, 67: 683-688, 1938.

Preoperative preparation of the vagina and perineum also depends upon mechanical cleansing and hence is no more effective than the care and understanding with which it is performed. With most patients, mechanical cleansing can best be accomplished by supervising the patient while she washes her own vulva. Particular attention should be paid to the creases alongside the labia minora and about the prepuce. The pubis, the vulva and the perineum should then be shaved carefully and the patient given a hot douche. Here again, synthetic detergents

do a better job than the traditional soap and water. A few drops of pHisoderm, for example, spread over the labia suffice to solubilize smegma quickly and gently with no mechanical assistance other than its application. Effective cleansing of the vagina can be accomplished by the instillation of a soda straw full (1 c. c.) of pHisoderm containing 3% G-11 into the posterior fornix of the vagina one hour prior to giving a hot douche of tap water. The straw is loaded and emptied with the aid of a small rubber syringe bulb.

CHAPTER XIII

AIR-BORNE CONTAMINATION

Talking through a mask over an open wound is bad enough when the subject pertains to the patient, but to do it for entertainment is sheer malpractice

—JEAN M STEVENSON AND MONT R REID, 1941¹

Contrary to widespread belief, the atmosphere is not a reservoir for bacteria. It merely serves as a vehicle for the transmission of organisms. Sterilized air is just as good a vehicle as is polluted air. The sources of bacteria in the air of the operating room are well known and the various reservoirs which distribute these organisms are susceptible to at least partial control. The most dangerous and ubiquitous source of pathogenic organisms is the forcibly expired air of the operating room personnel, including that of the surgeon and the patient. A second important source of potentially dangerous organisms is dust scuffed from the operating room floor,² brushed from clothing, or whisked into the air from bedding. A third source of organisms, which may be dangerous periodically or due to faulty operating room location, is street dust carried in on the shoes of the personnel or the dust from window sills when windows are opened during the summer months. Pigeon droppings, which decorate most institutional window sills, are often pellets of concen-

trated tetanus bacilli.³ Dusty ventilating air also may contribute organisms.

The problem of air-borne contamination is not new. The original work of Pasteur on fermentation focused so much attention on it that most of the early efforts at eliminating postoperative suppuration were aimed at controlling air-borne infection. As the bacteriology of the operating room was elaborated, it was recognized that other factors were more important than air-borne contamination and efforts to control it gradually relaxed. During the last twenty years, air-borne contamination has again been studied as the cause of a residuum of postoperative infection which escapes control by other methods. The magnitude of the problem is grossly apparent when the amount of dust settling through a ray of sun is noted. In terms of bacteria, it can be demonstrated that 30,000 to 60,000 viable organisms may contaminate an aseptic field per hour.⁴ The fact that still air is sterile emphasizes the rôle played by personnel in stirring up organisms just as they stir up dust and in expelling organisms from their nasopharynxes during forceful expiration.

¹ STEVENSON, J. M. and REID, M. R. in *Operative Surgery*, edited by F. W. BANCROFT. New York: D. Appleton-Century Company, Inc., 1941, p. 243. New edition to be published by J. B. Lippincott Co.

² CROSBIE, W. E. and WRIGHT, H. D. Diphtheria Bacilli in Floor Dust, *Lancet*, 1: 656, 1941.

³ RUSSELL, A. W. Pigeons as Possible Tetanus Carriers, *Brit. M. J.*, 2: 1220, 1937.

⁴ MELENEY, F. L. Infection in Clean Operative Wounds—A Nine Year Study, *Surg., Gyn. & Ob.*, 60: 264-276, 1935.

THE FILTERING ACTION OF MASKS

	TUBE COUNT (Indirect Contamination)		PLATE COUNT (Direct Contamination)	
	Average	Maximum	Average	Maximum
<i>Surgical Masks</i>				
Quiet breathing without mask	8	20	78	259
Quiet breathing with mask	19	99	91	315
Talking without mask	54	337	3,247	47,600
Talking with mask	35	120	194	620
<i>Industrial Masks</i>				
Quiet breathing without mask	4	15	20	65
Quiet breathing with mask	5	15	22	44
Talking without mask	31	62	1,089	4,200
Talking with mask	7	32	61	130

Hirschfeld⁵

The key to effective control of air borne contamination is the recognition and suppression of the source of the bacteria. The filtration of bacteria from a stream of dry air has proved ineffective⁶ because efficient filters offer so much resistance to the passage of air that it either circumvents the filter or the stream is stopped, making the application of that particular filter impracticable. Nevertheless, filtration of the expired air through masks is one of the most important means of checking wound infection. Electrostatic precipitation is effective but so far not feasible for operating room use.

Methods which destroy organisms suspended in the air are good but require special equipment. These range from devices for the sterilization by germicidal gas, usually formaldehyde, of the unoccupied operating room,⁶ to the continuous sterilization of the air circulated through an operating room by ozone,⁷ to the use of aerosols or ultraviolet radiation in the operating room,

itself. At the present stage of development of the art, as much can be done for the control of air borne contamination by the observance of simple common sense bacteriologic principles as is contributed by elaborate apparatus.

MASKING

Masking is the only effective technique for controlling the discharges from the nasopharynx. As recognized in 1888, the problem is not the control of the individual organisms which may be expired but rather the removal of gross droplets of saliva or mucus expelled during forced expiration.⁸ Masking controls this type of contamination effectively. An unmasked individual breathing either through the nose or the mouth expels only a few bacteria into the air as is shown in the table above.⁹ As soon as he talks, large numbers of organisms are ex-

⁵ WALTER, A. Electro-ionisation de l'air. *Bulletin officiel de la Société d'Electrothérapie et de Radiologie* October 1937.

⁶ STRAUSS, M. I. Sur l'absence de microbes dans l'air expiré, *Ann. de l'Inst. Pasteur* T2:181-186 1888.

⁷ HIRSCHFELD, J. W. and LAURE, P. J. Surgical Masks—An Experimental Study. *Surgery* 9:720-730 1941. C. V. Mosby Company.

⁸ MOORE, E. W. and MITCHELL, R. D. Air Filters for Surgical Water Sterilizers. Personal communication 1938.

⁹ GORDON, M. Fluctuations Acquis and Total Sterilization, *Presse Méd.*, 44:355 March 1936 (abstract). *J.A.M.A.* 106:1860 1936.

pelled forcibly, chiefly in the form of droplets of saliva and bits of mucus. Every forceful expiration is a miniature sneeze so far as the spray driven from the nasopharynx is concerned. Super-speed photographs of a sneeze show that the droplets are expelled at speeds as high as 100 feet per second.¹⁰ A mask catches the direct spray and accordingly reduces the number of bacteria in the air for the moment. As the droplets which impinge on the mask evaporate, the bacteria are deposited on the mask and subsequently entrain during quiet expiration. Thus, the air expired through a mask that has been worn for a few minutes carries more bacteria than that from an unmasked individual who is breathing quietly. The mask, therefore, acts as an averaging device. To afford the maximum protection, quiet breathing is imperative because a mask with minimal contamination is more effective than one which is saturated with organisms and hence contributes bacteria to the expired air. Certainly, anyone familiar with the facts will recognize instantly that the masking is so imperfect that those suffering from upper respiratory infections should keep out of the operating room.^{11, 12}

The best mask is made of six layers of 42×42 gauze, fashioned to hug the face so closely that the expired air is forced through the gauze rather than deflected behind the gauze. The filtering efficiency of such masks increases markedly after repeated washing because of matting and felting of the fiber. They catch as many as 90% of the organisms after having been laundered

twenty to fifty times.¹³ The resistance to air flow is sufficiently low so that they are effective filters. Four layers of 50×56 mesh muslin may also be used.¹⁰ The suitable masks are illustrated. One, figure 97, provides a metal strip which can be fashioned to fit the nose to prevent fogging of glasses, the other, figure 98, is an interesting modification which has found favor for communicable disease control but does not fit everyone comfortably.

The use of impermeable material as a mask is not desirable because the expired air is simply deflected around the edges of the mask and the atmospheric dissemination is the same as if no mask is worn.¹⁴ Such masks may be used advantageously where ultraviolet radiation is available to destroy bacteria in the air. Otherwise, the masks safeguard the wound only in that gross spitting is checked.

Masking gives the optimum control over contamination from expired air if the following rules are observed:

1. Masks should be changed as often as possible. Their effectiveness decreases rapidly after they have been worn several minutes.

2. Masks should fit the face snugly so that the air is forced to filter through the mask.

3. For maximum efficiency, forced expiration should be avoided. Talking, sighing, laughing, sneezing, coughing, all deposit bacteria on the masks, which subsequently contaminate the air expired during normal breathing.

4. New masks should be laundered before use to increase their filtering efficiency.

¹⁰ JENNISON, M. W. and EDGERTON, H. E. Droplet Infection of Air. High Speed Photography of Droplet Production by Sneezing, *Proc Soc Exper Biol & Med*, 43 455-458, 1940.

¹¹ Ultraviolet Curtains, editorial, *N.E J M*, 222 647, 1940.

¹² ASCROFT, P. B. Control of Sepsis in a Hospital in North Africa with Observations on Sulfathiazol Proflavine Powder in Surgical Wounds, *Lancet*, 1 594, 1944.

¹³ ROOKS, R., CRALLEY, L. J. and BARNES, M. E. Hospital Masks. Their Bacterial Filtering Efficiency and Resistance to Air Flow. A Comparative Study, *Pub Health R*, 56 1411, July, 1941.

¹⁴ ARNOLD, L. New Surgical Mask, Bacteriologic Air Filter, *Arch Surg*, 37 1008-1016, 1938.

5 Because masks are relatively ineffectual, anyone with upper respiratory infection is grossly negligent when he enters an operating room. The fact that those with strongly positive nasal cultures expelled hundreds to thousands more hemolytic streptococci than individuals with negative cultures¹⁶ is evidence compelling surgeons to keep "colds" out of the operating room.

The character of the contamination from dust is also susceptible to control. Pathogenic organisms are prevalent in any operating room where surgeons carelessly contaminate the floor with pus and blood either by incising abscesses and permitting the pus to squirt spectacularly to the floor, or by carelessly tossing sponges at, but not in, the kick pails. The circulating nurse who carries a dripping sponge from the kick pail to hang it on the sponge rack also contaminates the floor. Contaminated areas should be scrubbed immediately with a mixture of lime paste or 1:1000 solution of sodium hypochlorite to disinfect the area. It is the duty of everyone privileged to work in an operating room to protect the floor from contamination with pathogens.

Operating rooms must be kept scrupulously clean with soap and water. The use of dust free cleansers is imperative and surgeons must avoid scattering talcum powder because such particles contribute greatly to the dust in the air. Cleaning should be done by vacuum, preferably with the type of cleaner in which the exhaust is discharged outdoors. Dry mops and brooms must not be used. Cleaning should be done at least an hour prior to operation so that there is ample time for bacteria to settle from the air before the sterile field is exposed. Wood

floors and those covered with linoleum can be treated with spindle oil to allay dust. One liter of the oil is applied to 30 square meters of surface which has been scrubbed clean. The oil is noninflammable, odorless and not slippery when dry. Applications must be made two and five weeks after the initial oiling, thereafter at intervals of seven weeks¹⁸.

The bacterial count of air during sweeping or activity is markedly reduced by this treatment and with it the incidence of respiratory disease.¹⁷ The oil is deleterious to rubber tile floors and ineffective on tile or concrete.¹⁸ Ultraviolet irradiation of the latter types of floors may prove effective.¹⁹ For highly polished floors a mixture consisting of

Urea	50 gr
Ninol*	30 gr
Roccal (12.8%)	9 cc.
Distilled water q.s. ad.	1000 cc.

dries quickly so that it is not slippery but holds enough moisture to produce wetting of particulate matter contacting it. It retains its bactericidal power well but must be reapplied daily.¹⁸

Street shoes and clothing should not be worn in the operating room nor should those who care for patients with infected wounds or contagion enter the operating room with out changing clothes. The bedclothing of patients with contagious disease or infected

¹⁶ THOMAS, J. C. Reduction of Dust-borne Bacteria by Oiling Floors, *Lancet*, 2:123 1941

¹⁷ ANDERSON, P. H. R., BOGHANAN, J. A. and MACPORTLAND, J. J. Oiled Floors to Control Respiratory Infection, *Brit. M. J.*, 1:616, 1944

¹⁸ WRIGHT, J., CRUICKSHANK, R. and GUNN, W. The Control of Dust-borne Streptococcal Infection in Menstrual Wards, *Brit. M. J.*, 1:1611 1944

¹⁹ HOLLANDER, A., DO BOY, H. G., INURAHAM, H. S. and WHEELER, S. M. Control of Air-borne Microorganisms by Ultraviolet Floor Irradiation, *Science* 99:130-131 1944

A synthetic detergent manufactured by Ninol Laboratories, Chicago, Illinois

¹⁶ ROBINSON, O. H., HAMBURGER, M., LOVELL, C. G. PUCK, T. T., LEMON, H. M. and WISE, H. A Study of the Nature and Control of Air-borne Infection in Army Camps, *J.A.M.A.*, 126:993-1000 1944

NATURAL DISAPPEARANCE CURVES FOR BACTERIA IN AIR

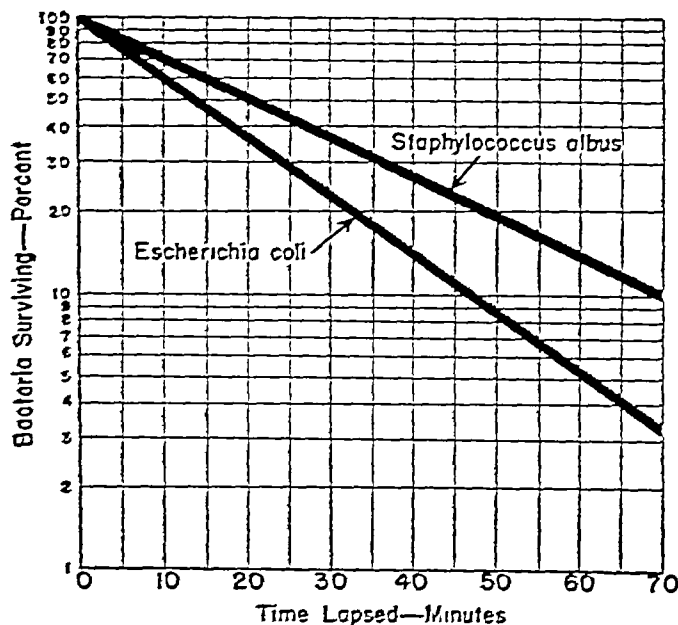


FIGURE 134 Williamson & Gotaas²⁵

DISAPPEARANCE CURVES WITH AEROSOLS

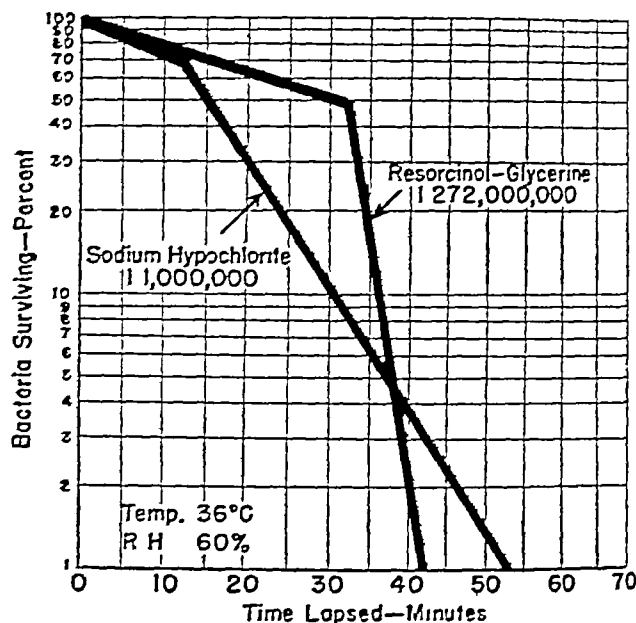


FIGURE 135 Williamson & Gotaas²⁵

wounds should not be taken to the operating rooms, nor should their dressings be carelessly thrown about, particularly when they are dry. Pathogenic organisms do not generate spontaneously; they are carried from patient to victim by well-meaning doctors and nurses^{20 21, 22} Clothing and blankets can be treated with a dust-laying emulsion to reduce by 98% to 100% the number of bacteria thrown into the air.²³ The technic is simple. The clothing is laundered and given a final rinse in a 20% solution of a stable water emulsion of white oil * Its appearance and texture is unaffected by the treatment Treated blankets do not create a fire risk.

Air-borne bacteria disappear rather

quickly. The rate of natural disappearance varies greatly for different bacteria and is related to the relative humidity of the air.²⁴ For example, the rate of disappearance of *B. coli* is more than doubled by increasing the relative humidity from 45% to 90% The normal rate of disappearance of bacteria from air follows approximately a straight logarithmic curve, figure 134²⁵

Recent investigation shows that air can be effectively disinfected by dispersing germicides in the air as a mist²⁶ The mode of action varies Some germicides, typified by

²⁰ FILES, A. A., SCHWABACHER, H., CUNLIFFE, A. C., ROSS, J. P., SPOONER, E. T. C., PILCHER, R. S. and WRIGHT, J.: Hospital Infection of War Wounds, *Brit M J.*, 2: 855, 1940

²¹ Secondary, Streptococcal Wound Infection, Editorial, *N.E.J.M.*, 230:652, 1944

²² The Individual Streptococcus Carrier, Editorial, *J.A.M.A.*, 125:556, 1944.

²³ VAN DEN ENDE, M. and THOMAS, J. C. The Treatment of Bedclothes with Dust-laying Oils, *Lancet*, 2:755, 1941

* Directions for large scale treatment of hospital bedclothes have been elaborated by the British Laundries Research Association. HAPWOOD, F. C., POWNEY, J., EDWARDS, E. W. A New Technique for the Application of Dust-laying Oils to Hospital Bedclothes, *Brit M J.*, 1:615, 1944

²⁴ WELLS, W. F. and RILEY, E. C.: An Investigation of the Bacterial Contamination of the Air of Textile Mills with Special Reference to the Influence of Artificial Humidification, *J Indust Hyg & Toxicol*, 19:513-561, 1937

²⁵ WILLIAMSON, A. E. and GOTAAS, H. B. Aerosol Sterilization of Air-borne Bacteria, *Indust Med*, 11:40-45, 1942

²⁶ Germicidal Gas, editorial, *J.A.M.A.*, 118:734, 1942.

hexylresorcinol or sodium hypochlorite, are active because each small droplet contains the same concentration of germicide as the parent solution which is atomized and will destroy bacteria on contact because an effective concentration of germicide is quickly built up about the bacteria. Others, for example, the glycol group, are lethal principally because of the rapid evaporation of the aerosol droplets with the liberation of the glycol gas. The concentration of germicide necessary for disinfection of the air is surprisingly small. One part of propylene glycol to 2,000,000 or 3,000,000 parts of air is effective against influenza virus.¹⁷ A concentration of sodium hypochlorite, one part of mist in 1,000,000 parts of air, or a mist concentration of one part of resorcinol-glycerine aerosol to 272,000,000 parts of air, is effective, figure 135.¹⁸

Available aerosols are not practicable for operating room use because they are either irritating to the eyes and lungs or they are toxic. Ultimately, a nontoxic, nonirritating, invisible, noninflammable, noncorrosive, persistent aerosol will be developed which will not leave a residue on walls and furniture. At present, aerosols are effective for the fumigation of air in empty rooms or when used as a wash for the disinfection of exposed surfaces. The most readily applicable one is 0.5% solution of sodium hypochlorite dispersed in a closed room with a power atomizer. The room should be quarantined for one hour. Limitations which must be remembered are that dry organisms are not killed and that a relative humidity above 65% must be attained. The hypochlorite disappears from the air rapidly. Volatile organic compounds, phenol and cresol for example, neutralize the hypochlorite.¹⁹

¹⁷ ROBERTSON, O. H., LOOSLI, C. G., PUCK, T. T., BROG, E. and MILLER, B. F. The protection of mice against infection with air-borne influenza virus by means of propylene glycol vapor. *Science* 94:612-613 1941

Another promising aerosol, triethylene glycol, awaits the design of apparatus for dispersing and controlling the concentration of the vapor in large rooms. It is nontoxic, bactericidal, and virucidal in concentrations of one volume glycol to 2×10^{11} volumes of air²⁰ with a relative humidity of 40%.

Ultraviolet radiation is the only applicable method for sterilizing the air in operating rooms at the moment.²¹ The technique is spectacularly novel, particularly to the lay mind, and little has been written about its limitations.

When sunlight is dispersed through a prism, the energy waves are sorted according to their wave lengths and the typical refraction pattern of the familiar rainbow can be demonstrated. The visible spectrum is represented in figure 136 as that area of the electromagnetic spectrum extending from the violet (3970 Å) through the rainbow colors to red (7594 Å). In the region immediately below the violet end of the spectrum lie radiations important to the good health of animals and plants. They are imperceptible to human beings and are known as ultraviolet radiation. The band of ultraviolet includes wave lengths of 136-3000 Å. At the opposite end of the visible spectrum, the infrared radiations are more familiar because of the perceptible glow, appreciated as warmth, stimulated by the invisible infrared rays.

It has long been recognized that ultraviolet radiation has definite physiological effects, several of which are of interest in this application. It produces erythema of the

¹⁸ BOURDELLON, R. B., LEWELL, O. M. and LOVELOCK, J. E. Sneezeing and Disinfection by Hypochlorites, *Brit. Med. J.*, 1:42-44 1942.

¹⁹ ROBERTSON, O. H. Disinfection of Air by Germicidal Vapors and Mists, *Am. J. Pub. Health*, 34 887 1944

²⁰ HART, D. Sterilization of the Air in the Operating Room by Special Bactericidal Radiant Energy. *J. Thoracic Surg.*, 6:45-81 1936.

ELECTROMAGNETIC-WAVE SPECTRUM

UNIFORM VELOCITY 30,000,000,000 CENTIMETERS PER SECOND

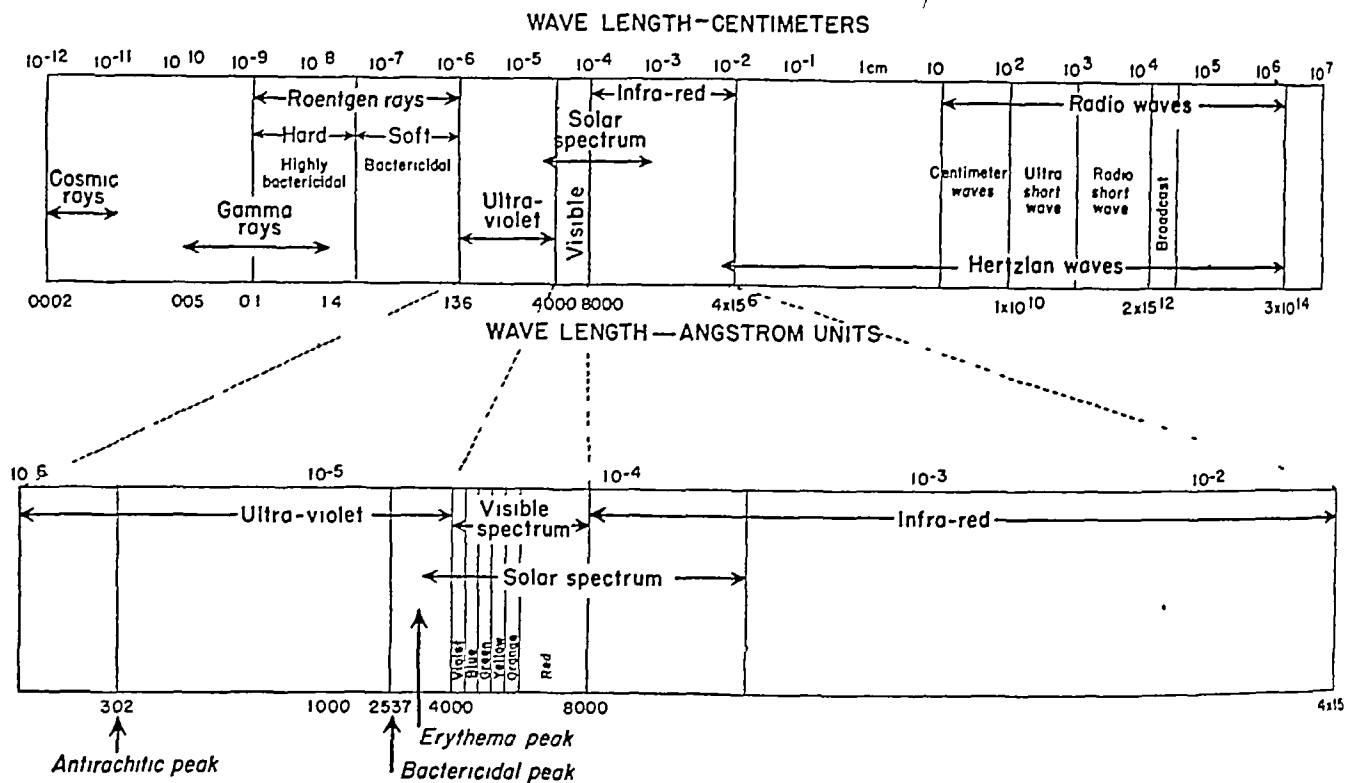


FIGURE 136

untanned skin which is associated with the production of the tyrosine responsible for the pigmentation of tanning³¹ It also causes the change of histidine to histamine which is responsible for the local and general reaction experienced after exposure to ultraviolet radiation. The antirachitic effect is well known. Another effect is the bactericidal one. Identification of the wave lengths responsible for these actions of ultraviolet has been the result of gradual delineation by many investigators. The peak of bactericidal activity lies in the region of 2537 Å, that for antirachitic activity is optimum at 302 Å, while that for erythema production lies at 2975 Å³² Selective filtration systems are available which make it possible to use radiation within bands of specific wave lengths. This is particularly true when such

³¹ LUCKIESH, M and TAYLOR, A. H. Production of Erythema and Tan by Ultraviolet Energy, *JAMA*, 112 2510-2511, 1939

filtering systems are applied to ultraviolet generators emitting a continuous spectrum where as much as 88% of the energy can be limited to the band approximating 2537 Å.

Merely defining the quality of ultraviolet radiation used is not sufficient for bactericidal processes, any more than determining the quality of saturated steam being used is sufficient for sterilization. The quantity of ultraviolet is readily measured by physical methods involving the use of a photo-electric cell, protected by a filter which limits the radiation to a selected range, to meter the electric current produced by the radiant energy into a condenser. When full, this condenser discharges through a vacuum tube and registers each discharge on an electrically

³² HAUSER, K. W and VAHLE, W. Die Abhängigkeit des Lichterythems und der Pigmentbildung von der Schwingungszahl (Wellenlänge der erregenden Strahlung), *Strahlentherapie*, 13, 41-71, 1921

operated counter. Because the counter clicks at each discharge, the quantity of radiation required to cause the condenser to discharge is known as a "click."³³ It is much like measuring the strength of a man by letting him pump water from a well into a bucket and expressing strength as the "splash" made every time the bucket is emptied.

The lethal period for ultraviolet radiation is determined in two ways. One method is to expose a limited area of blood agar plates, seeded with bacteria, to ultraviolet radiation so that the unexposed portions serve as a control. The end point for this method averages five minutes' exposure to ultraviolet radiated at 22 clicks per minute. The result of a typical experiment on *staphylococcus aureus* is illustrated in figure 137, which shows an end point at six minutes.³⁴ The more crucial method involves the determination of the intensity of radiation necessary to destroy bacteria suspended in air. Ultraviolet is approximately nine times as effective against air borne bacteria as it is against those seeded on the blood agar plates. Thus, at an intensity of 13 clicks per minute, bacteria falling through ultraviolet radiation at a rate of three feet in one minute are destroyed. The effect of varying intensity of radiation is tabulated below.

LETHAL INTENSITY OF ULTRAVIOLET FOR BACTERIA IN AIR

INTENSITY OF RADIATION	TEST	CONTROL
Clicks per minute	Colonies recovered in 1 minute	Colonies recovered in 1 minute
4	51	356
6	26	118
10	6	220
13	3	535
16	2	327

Krausl Cametti & Melroy³⁴

DETERMINING LETHAL PERIOD FOR ULTRAVIOLET RADIATION

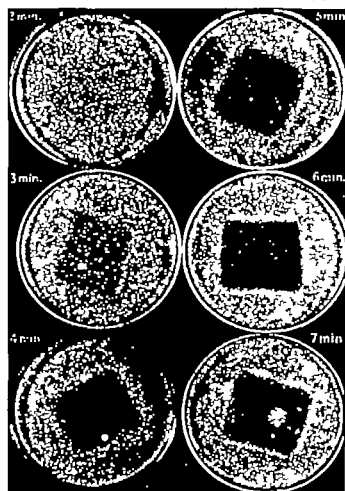


FIGURE 137 Krausl Cametti & Melroy³⁴

In addition to the obvious erythema caused by ultraviolet, other dangerous effects are recognized. A detailed study of the action of ultraviolet radiation upon the exposed intestines of guinea pigs has demonstrated sufficient tissue injury to make its indiscriminate use unwise. The histidine-histamine effect stimulated in the exposed intestines is sufficient to cause injury ranging from a mild reaction to frank gangrene. The production of adhesions between contiguous loops of exposed gut is a good measure of tissue injury and permits the correlation of the minimal lethal exposure for bacteria with the maximum exposure that

³³ RENTCHLER, H. C. An Ultraviolet Light Meter *J. Am. Inst. of Elec. Eng.*, 49:113 February 1930

BACTERICIDAL EFFECT VS. TISSUE TOLERANCE OF ULTRAVIOLET

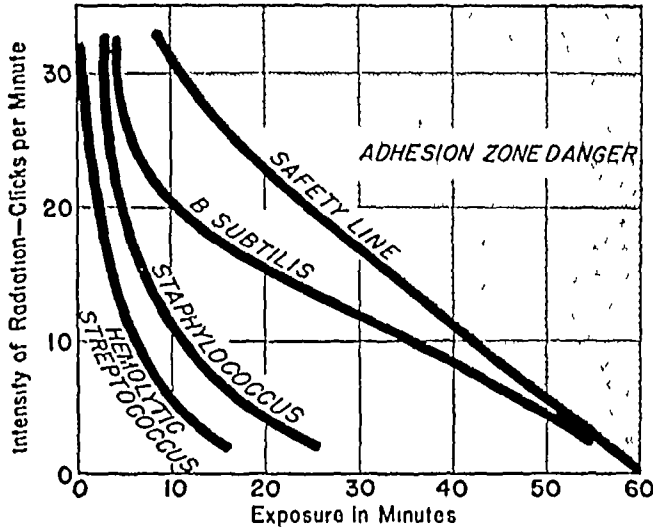


FIGURE 138 Kraissl, Cimiotti & Meleney ³⁴

is safe for tissue, figure 138 ³⁴ Correlation of the exposure to ultraviolet and the resultant photo-ophthalmia shows variation from slight passing conjunctival hyperemia to extensive inflammation resulting in permanent interstitial corneal opacity ³⁵ The skin, tissues, and eyes are injured by exposure to ultraviolet and must be properly protected

Certain additional limitations must be considered in applying ultraviolet radiation. The germicidal action of ultraviolet is a surface effect only The radiation does not penetrate the surface of liquids but is readily reflected, hence, droplets are not sterilized The penetration of bactericidal wave lengths in normal skin is negligible The intensity of the surface effect decreases as the square of the distance from the radiator, so that care must be taken to provide the proper distribution for bactericidal action, while avoiding excess exposure

Shadows protect bacteria from the lethal action of radiation, hence, every surface of an object must be exposed to ultraviolet for total sterilization. The organisms harbored in dried pus are protected by the shadows of the organisms on the surface of the pus

The action of ultraviolet is not instantaneous and sufficient exposure must be provided to sterilize Thus, it requires one minute's exposure to ultraviolet radiation having an intensity of 13 clicks per minute to destroy air-borne bacteria. In practice, this corresponds to the sterilization of organisms falling through ultraviolet at the rate of three feet per minute. Ultraviolet is not effective therefore in destroying organisms as they are expelled forcibly from the masked mouth or nose during talking, laughing, sneezing, sighing, or coughing, where speeds as high as 100 feet per second may be attained The ozone generated by ultraviolet lamps is a hazard that must be recognized Concentration as low as one part in 25,000,000 is irritating to the mucous membranes of the upper respiratory tract ³⁶ Adequate ventilation must be provided to prevent concentrations great enough to cause a detectable odor ³⁷ Ultraviolet lamps suitable for disinfecting purposes should have a minimum intensity of radiant energy in the bactericidal wave length of 2537 Angstroms of 20 micro-watts per square centimeter at a distance of one meter perpendicular to the plane of the lamp ³⁷ A minimum useful life of 4000 hours has been established for ultraviolet lamps Because there is no other way of determining whether the lamps are emitting lethal radia-

³⁴ KRAISSI, C J, CIMIOTTI, J G and MELENKY, F L Considerations in the Use of Ultraviolet Radiation in Operating Rooms, *Ann Surg*, 111 161-185, 1940

³⁵ VERRILLI, F H and BRILL, L The Pathological Effects of Radiant Energy on the Eye — An Experimental Investigation, *Proc Am Ac Arts and Sciences*, 51 629, 1916

³⁶ WITHERIDGE, W N and YAGLOU, C P Ozone in Ventilation Its Possibilities and Limitations, *Heating, Piping, Air Conditioning and Ventilating*, 11 648-652, 1939

³⁷ COUNCIL ON PHYSICAL THERAPY Acceptance of Ultraviolet Lamps for Disinfecting Purposes, *JAMA*, 122.503, 1943

ULTRAVIOLET INSTALLATION IN OPERATING ROOM

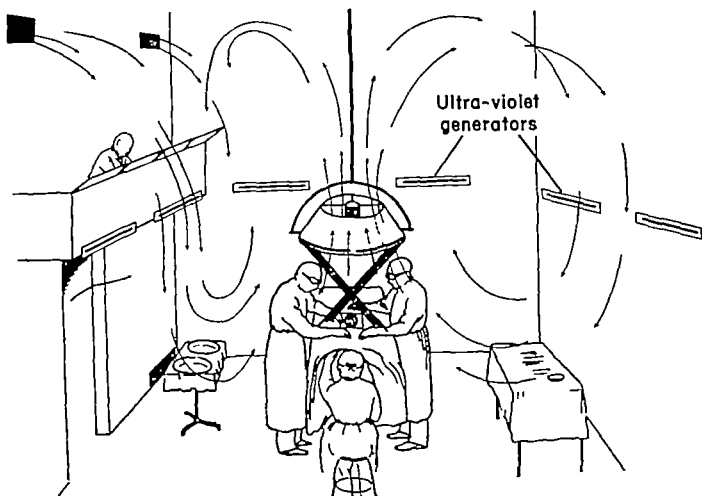


FIGURE 139

Krassl, Cimaoli & Melaney²⁴

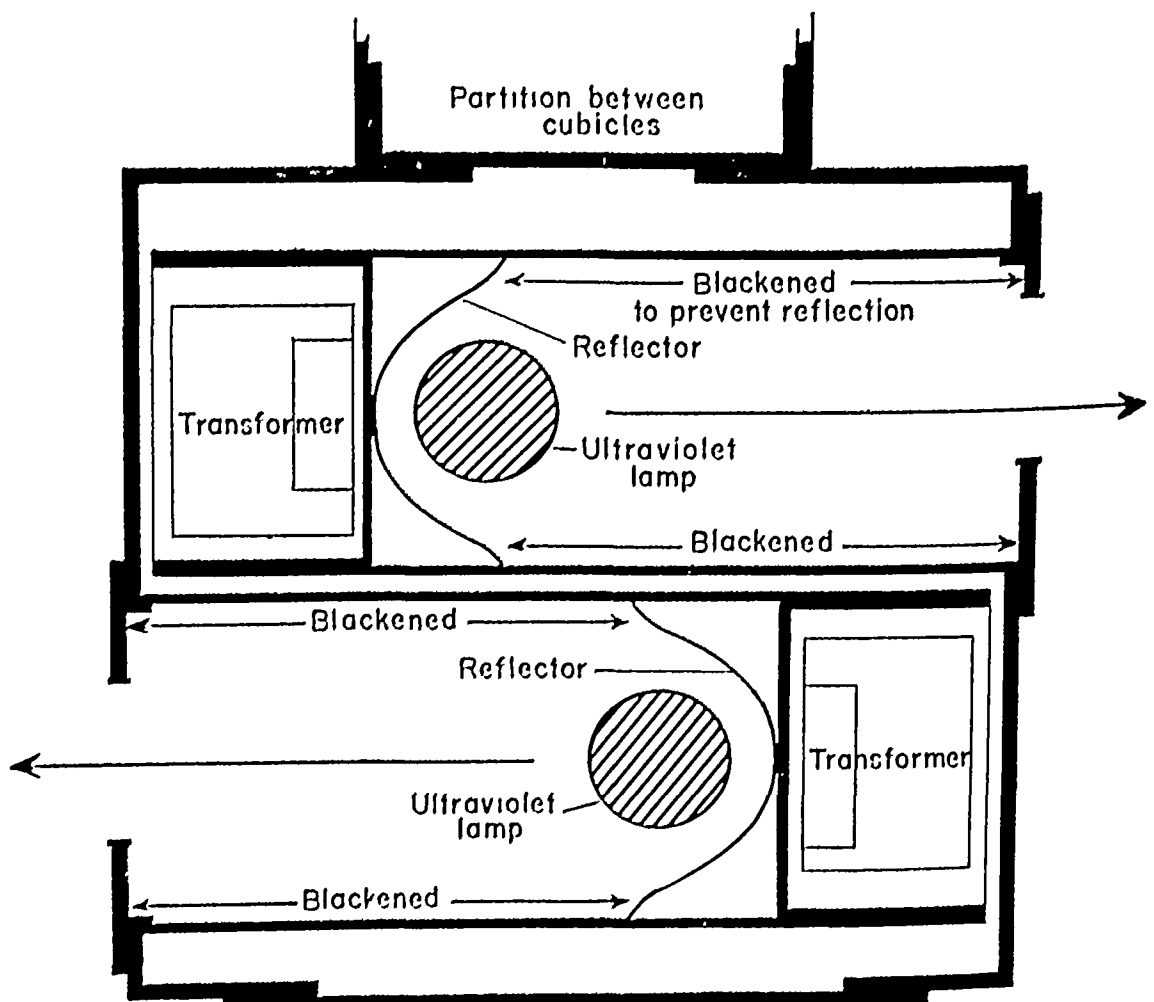
ion, they must be tested with an ultraviolet meter at monthly intervals. Those found faulty must be replaced if they are the type which emit excess radiation when new and deteriorate to the minimum at 4000 hours. If they are the kind that are provided with a voltage regulator to compensate for the decrease in intensity of emitted radiation, appropriate adjustment should be made. Lamps must be cleaned daily to prevent the accumulation of a barrier of dust.

Several technics for the use of ultraviolet have been described. Figure 139 illustrates a suggested technic which has proved effective. The periphery of the operating room is fitted with a series of 30" ultraviolet generators, each with a control to regulate

its intensity. In use, the radiation in any part of the room is measured and adjusted to provide safe control of air borne bacteria as indicated in figure 138. Because the greatest contamination of air occurs at the beginning of the operation when the activity of the operating room personnel is at its peak, the intensity is kept high and can be lowered as delicate tissues are exposed.²⁵ The air at the operative field itself is disinfected by an ultraviolet generator located about the periphery of the operating light. When fitted with suitable reflectors, it is possible to maintain an optimum radiation

²⁴ KRASSL, O. M. and BROOKER, J. W. Incidence of Air borne Bacteria in the Major Surgery of the Multnomah County Hospital, *Surgery* 41:755-761 1938.

The floor plan shows a rectangular ward layout. At the top are four cubicles labeled CUBICLE 1, CUBICLE 2, CUBICLE 3, and CUBICLE 4. Below these is a horizontal PASSAGE. At the bottom are CUBICLE 6 and CUBICLE 5. Between the passage and the bottom cubicles is a CHARTING ROOM. A WARD CORRIDOR runs along the left wall. Arrows indicate door locations: CUBICLE 1 has a door to the corridor; CUBICLES 2, 3, and 4 have doors to the passage; CUBICLE 6 has a door to the passage; CUBICLE 5 has a door to the corridor. Windows are indicated by pairs of arrows on the outer walls of each cubicle. A curved line in the corridor indicates a turn or a specific area.



of 13 clicks per minute, which will kill over 99% of the organisms suspended in the air above the operative site. In figure 139, the chimney effect of the light is depended upon to keep the organisms suspended in the air for the lethal period of one minute. This technic permits the exposure of viscera safely for periods of forty minutes.

The operating room staff must be protected from irradiation conjunctivitis by clear glass goggles. The skin of the head and neck are best protected by a wide brimmed helmet fitted with a snood like skirt to protect the back of the neck.

The use of ultraviolet radiation for the sterilization of air in the operating room should be limited to those few surgeons who are cognizant of the biophysics involved and who understand its limitations and its hazards. Ultraviolet sterilization of the air is an unjustifiable luxury in any hospital unless all the other equipment essential for the safety of the patient has been provided and unless an ideal aseptic technic is wholeheartedly enforced because more organisms are introduced on fingers, instruments, and dressings than ever fall into the wound from the air.

Ultraviolet radiation can be used most advantageously to control the spread of respiratory infections. To be successful, however, an adequate installation is essen-

tial. Makeshift installations may be dangerous and ineffectual. Radiation of only the upper air is useless.³⁹ Curtains or barriers of ultraviolet of adequate intensity to effect practically 100% killing must be used. Safeguards against excessive exposure of the occupants of the room must be provided. In aiseways and the like where transient personnel carry on their work, the intensity of radiation should not exceed one-half microwatt per square centimeter for a continuous exposure of eight hours or one-tenth microwatt per square centimeter for a continuous exposure of 24 hours per day.⁴⁰

An effective technic for the use of ultraviolet curtains is shown in figure 140, 1.³⁹ The direction of the ultraviolet rays is shown by the arrows; the source is a series of lamps mounted, detailed in figure 140, 2, on either side of the passageways so that the curtain of lethal rays extends completely across the passage. Since all partitions extend from floor to ceiling, each cell is effectively isolated. Ventilating air is sterilized by ultraviolet before liberation into the ward.

³⁹ ROBERTSON, E. C., DOYLE, M. E. and TEDALL, F. F. Use of Ultraviolet Radiation in Reduction of Respiratory Cross-infection, in a Children's Hospital, *J.A.M.A.*, 121:908, 1943.

⁴⁰ COUNCIL OF PHYSICAL THERAPY: Ultraviolet Lamp for Disinfecting Purposes—Introductory Statement, *J.A.M.A.* 123:92, 1943.

CHAPTER XIV

OPERATING ROOM TECHNIC

During the battle of El Alamein, one surgical team did 100 operations, $\frac{2}{3}$ of them on brain wounds, in 12 days. This experience convinces us that time is saved by not skimping the preliminaries. Careless placing of the patient on the table, niggardly shaving and indifferent arrangement of the drapes all make for slipshod or slow and wearisome operating.

— P B ASCROFT, 1943¹

The modern operating room contributes seven essentials for safe surgery.

1. A comfortable, dust-free environment
2. Facilities for safe anesthesia
3. Adequate, controlled illumination
4. Sterile instruments and supplies
5. Equipment for optimum positioning of the patient
6. A simple technic for draping the patient.
7. Accessory tables so that the surgeon has an ample field on which to work

The last four of these essentials have become the responsibility of most operating room nurses and represent their contribution to the success of an operative procedure. This chapter concerns itself with these duties.

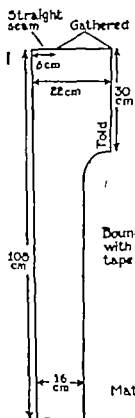
Operating room technic must be so simple that the anesthetist, the nurse, the surgeons, and the patient can arrive together and prepare for the operation simultaneously. If well organized, everyone contributes his share in the preoperative set-up without delay or inconvenience to any member of the surgical team. The technic to be de-

scribed makes the attainment of this goal feasible anywhere. Its success depends upon the intelligent anticipation of the surgeon's needs and the standardization upon several sterile kits which provide everything required for the surgical procedure. As explained in the preceding chapter, these kits can be sterilized and kept on hand and need only be opened immediately prior to use. The routine for each member of the surgical team will be described and his contribution to the preparation for a laparotomy will be correlated with that of the others.

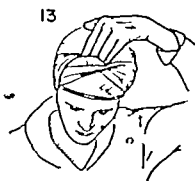
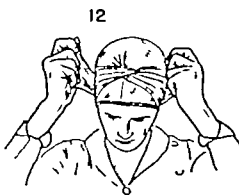
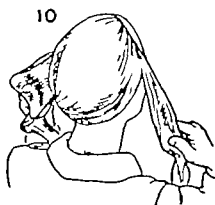
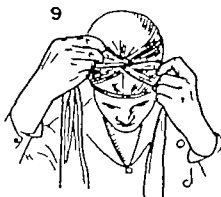
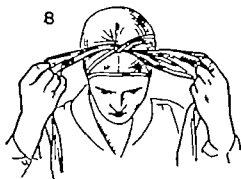
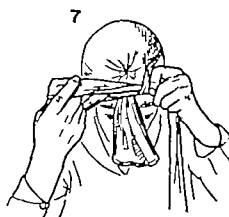
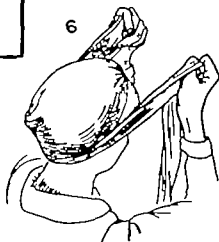
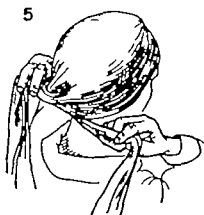
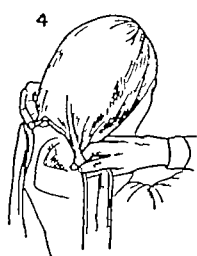
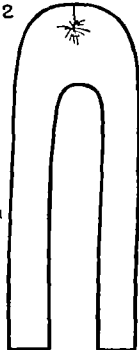
When the patient and the complete surgical team are all in the operating room, the patient is lifted to the operating table and anesthetized. Meanwhile, those who are to enter the sterile field discard their street clothes and shoes and dress in freshly laundered operating suits and recently cleansed shoes. Clean caps or turbans are adjusted to confine the hair. Turbans are more effective than caps for women and are easy to make and put on, figure 141. The instrument man selects the proper instruments, arranges them in a tray or bucket and puts them in the sterilizer. While the members of the team disinfect their hands and arms,

¹ ASCROFT, P B. Treatment of Head Wounds Due to Missiles, *Lancet*, 2 211, 1943

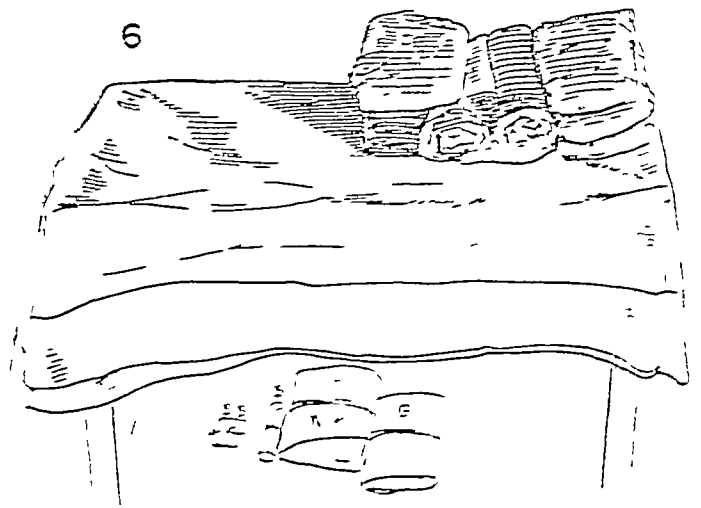
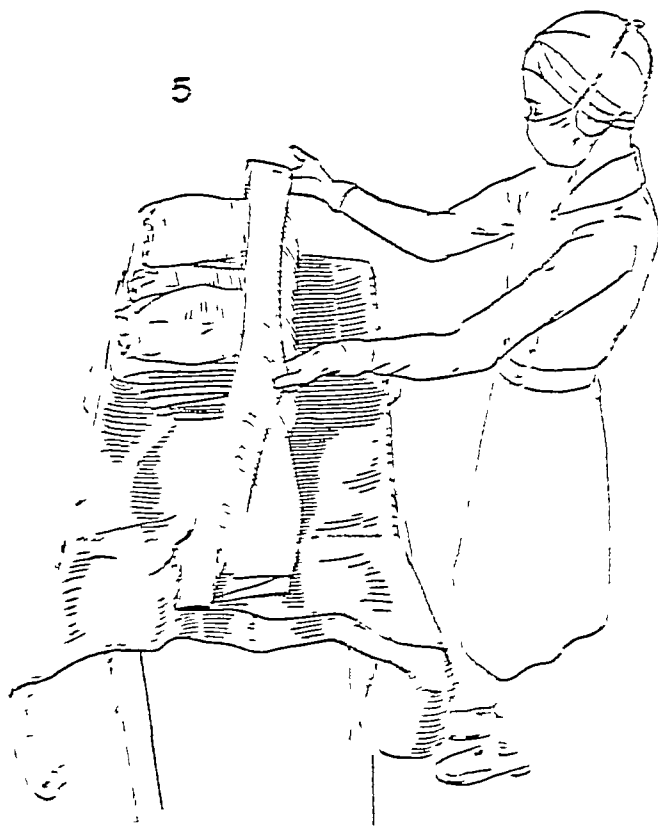
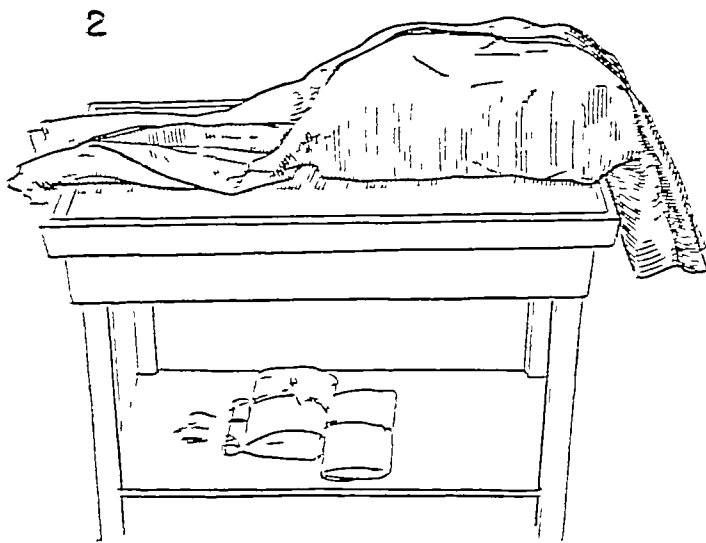
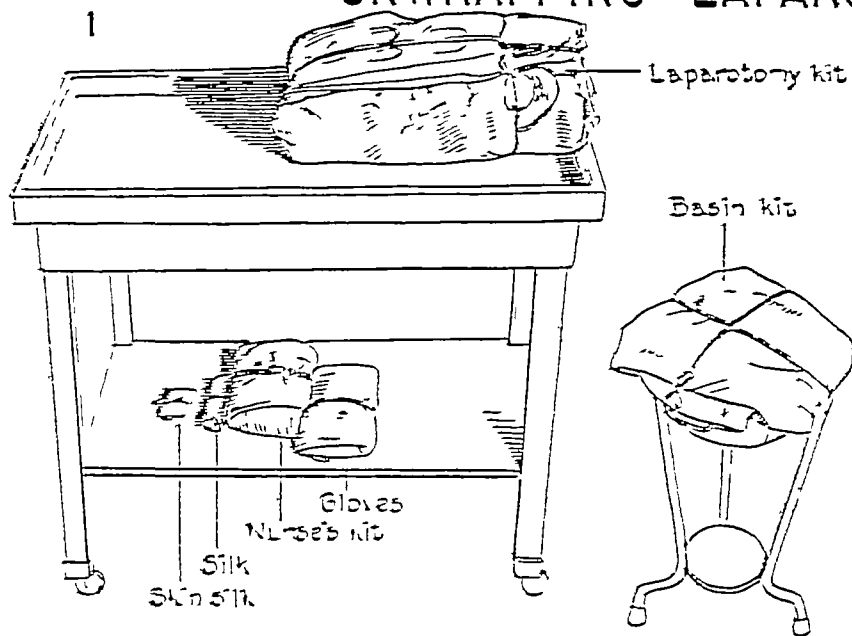
PUTTING ON NURSE'S TURBAN



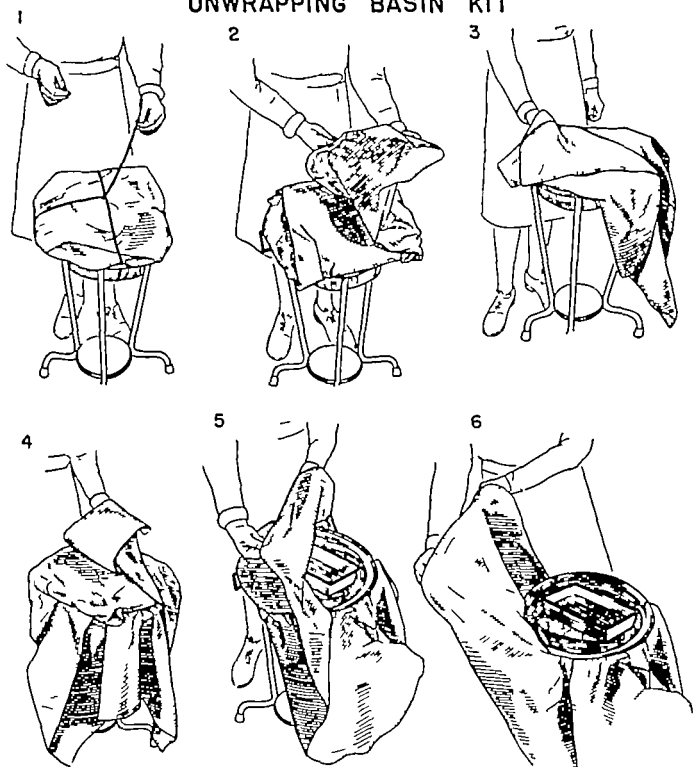
Material-cotton net



UNWRAPPING LAPAROTOMY KIT



UNWRAPPING BASIN KIT

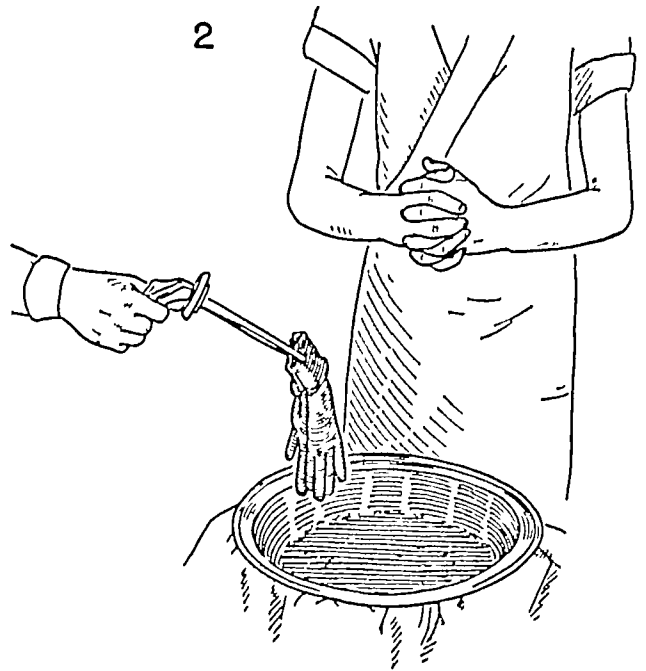


WET GLOVE TECHNIC

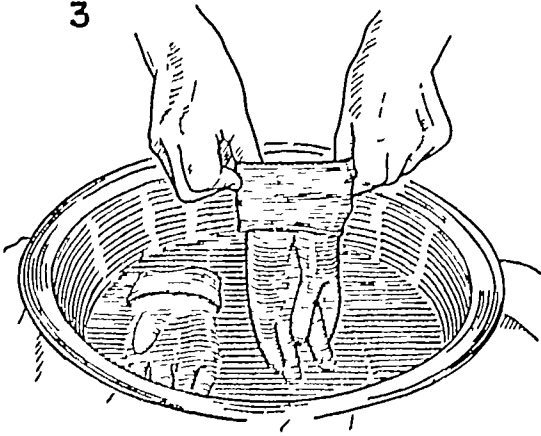
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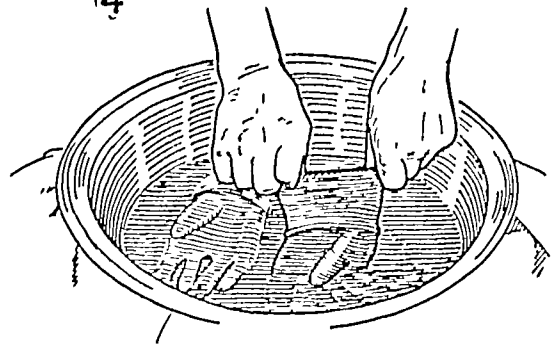
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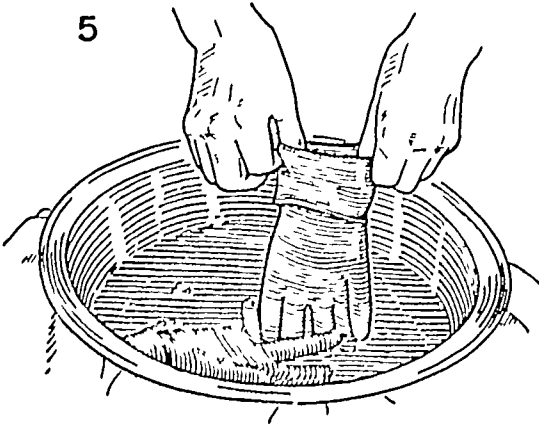
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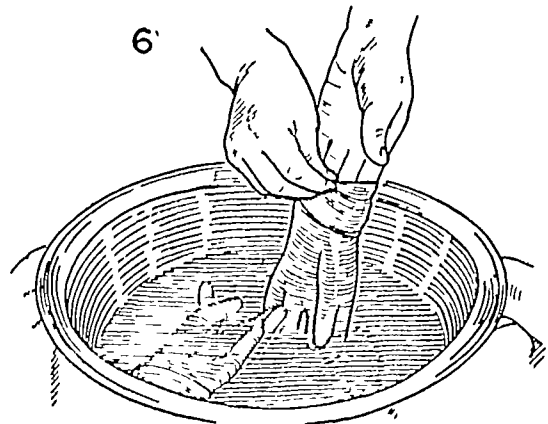
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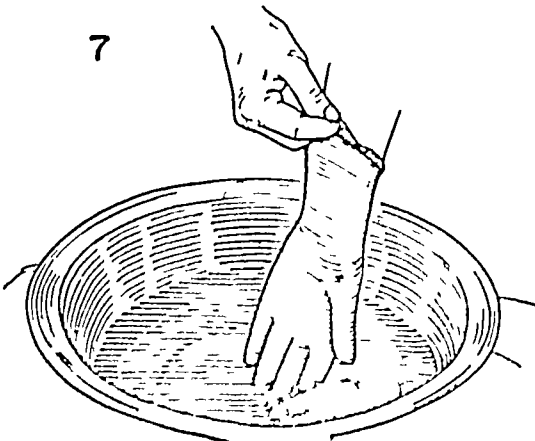
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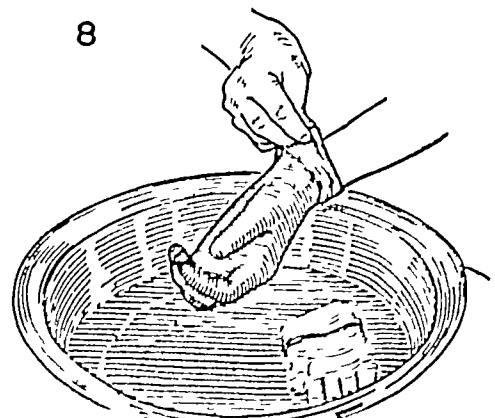
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the circulating nurse gets out the following packages of sterile supplies, figure 142, 7

1 Appropriate package of dry goods for a laparotomy, figures 75 to 78

- 4 abdominal flats
- 2 fluffs
- 6 Mikulicz pads
- 1 package of sponges
- 18 towels (6 folded for draping the skin, 1 fanfolded)
- 1 abdominal sheet
- 4 gowns

2 Dry goods for instrument table

- 1 large sheet
- 1 gown
- 1 towel

3 Basin kit for major procedure, figures 126 and 127

- 4. Nurse's kit, figure 128
- 5 Package of sterile gloves, figures 116 to 121
- 6 Sterile silk, figures 123-124
- 7 Sterile skin sutures, figure 125

The first package to be opened contains the dry goods for the nurse's table. Because the dry goods in this package were located in a specific position on the sheets which comprise the sterilizing wrapper, figure 75, 5, care must be taken to locate the package properly so that the stack of dry goods will be in its intended position. For most procedures, the dry goods are located in the right-hand rear corner of the table. For perineal work or for some neurological procedures, it is better to locate the stack of sterile goods in the center. Standing at the front of the table, the circulating nurse opens the library tie and removes the cord. The folded ends are turned out and loosened, figure 142, 2. The cuffed back fold is grasped at either end and the edge of the sheet is held tautly as it is pulled over the edge of the table, figure 142, 3. From the opposite side of the table, the second cuffed edge of the wrapper is held as before and draped over the edge of the table, exposing one half of the sterile contents, figure 142, 4, 5. Returning to the

front of the table, the edge of the last cuff is carefully picked up and the remaining fold is pulled back to cover the first one, draping the nurse's table with four thicknesses of muslin, figure 142, 5, 6.

The basin kit is fitted into the basin stand by the circulating nurse. The library tie is pulled loose and the cord removed, figure 143, 1. The presenting corner of the wrapper is grasped in the left hand, figure 143, 2, and peeled off. The corner of the next fold is grasped and turned down, figure 143, 3. To avoid reaching across a sterile field, the nurse then takes a position so that the turned-back cuff of the third corner can be pulled toward her, figure 143, 4. Finally, the cuffed edge of the last corner of the wrapper is pulled back, figure 143, 5, exposing the sterile kit supported on a stand draped with a sterile sheet, figure 143, 6.

The scrubbed nurse, who has completed the disinfection of her hands, puts on a pair of gloves in a central glove basin maintained specifically for the purpose.

The key to putting on wet gloves easily is to keep them full of slippery fluid; 1 5000 aqueous Zephiran serves the purpose admirably. The gloves used by the scrubbed nurse are removed from their sterile package with transfer forceps and dropped directly into the glove basin, figure 144, 2. One of the gloves is grasped by the rolled-back cuff, care being taken not to touch the outer surface of the glove, figure 144, 3. The glove is scooped full of solution, figure 144, 4, 5, and while the cuff is held with the fingers of one hand, figure 144, 6, the closely approximated fingers and thumb of the opposite hand are insinuated into the glove with a smooth, uninterrupted motion, the object being to get the hand and fingers into the gloves before the fluid which distends it can escape, figure 144, 7. When the glove is on, the cuff is pulled away from the arm and the excess fluid is discharged by clenching the

PASSING NURSE'S KIT

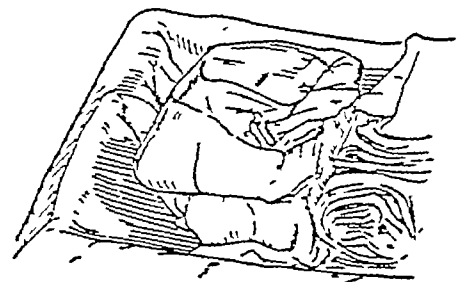
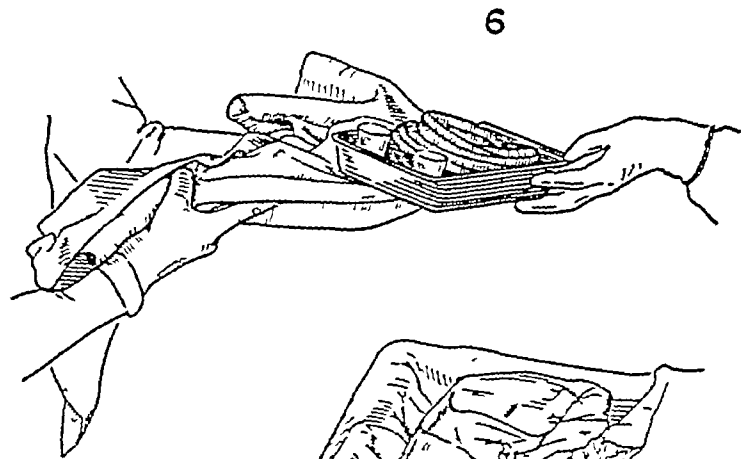
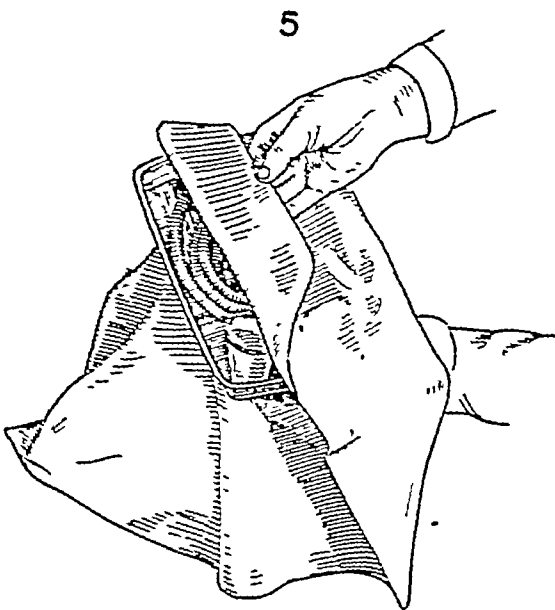
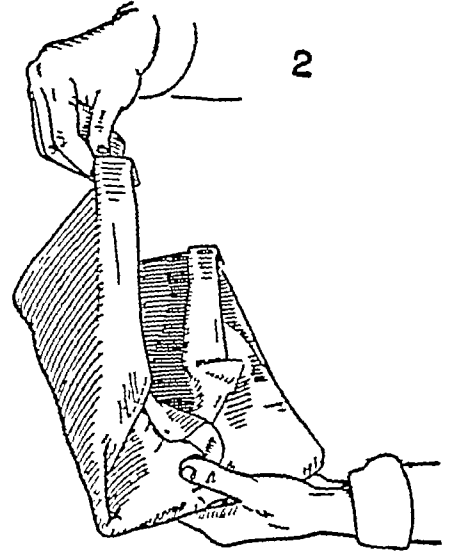
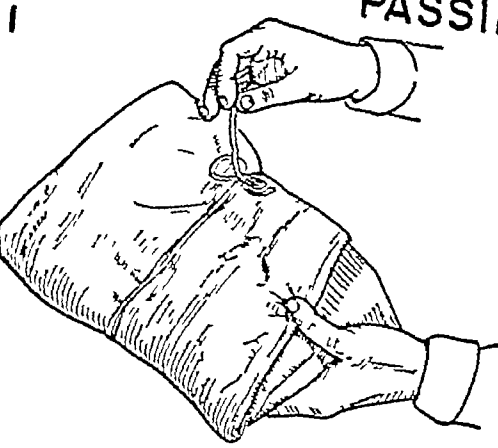
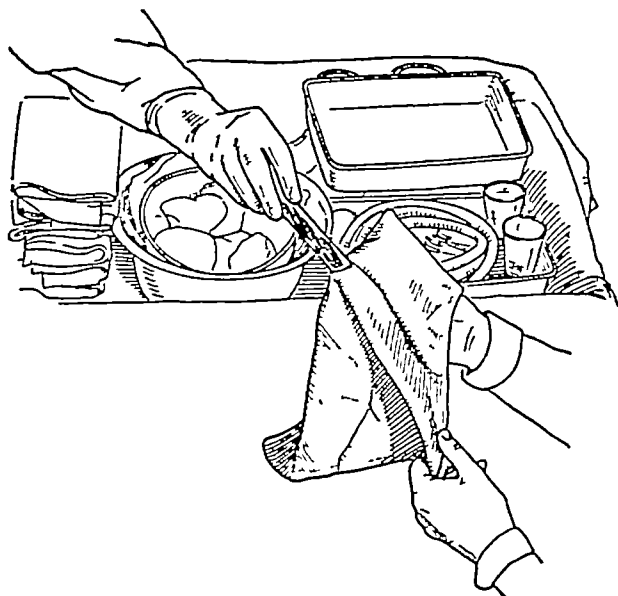


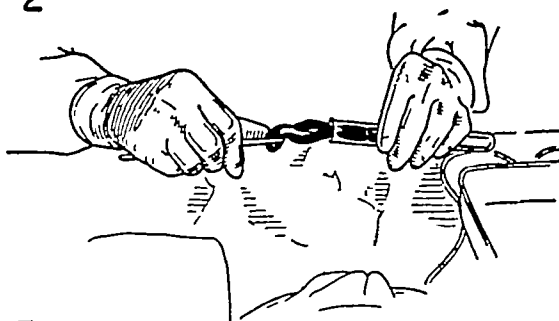
FIGURE 147
[208]

ARRANGING NONABSORBABLE SUTURES

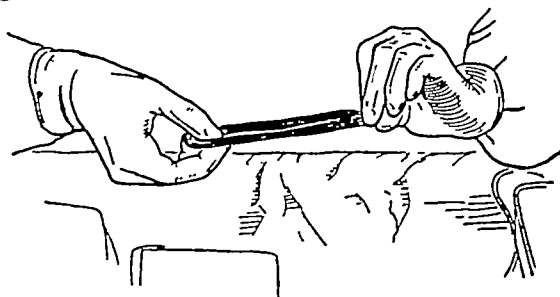
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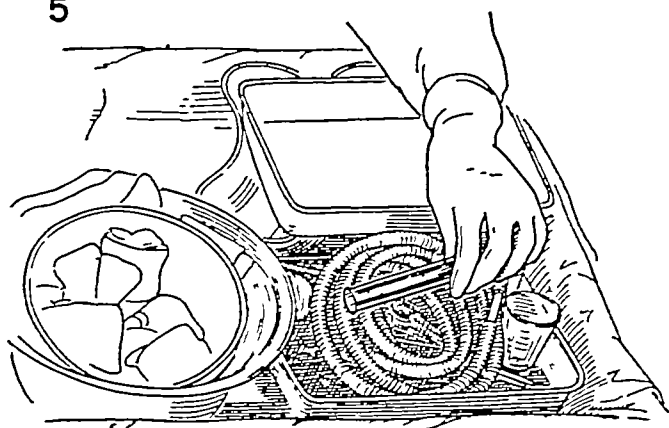
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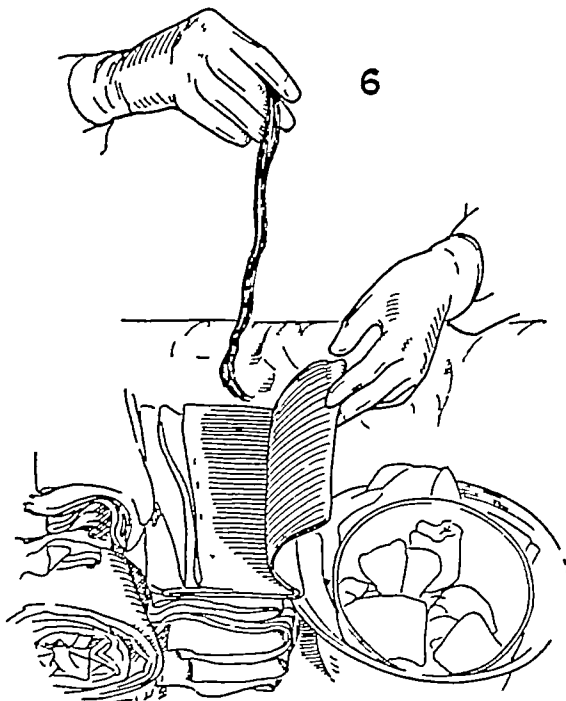
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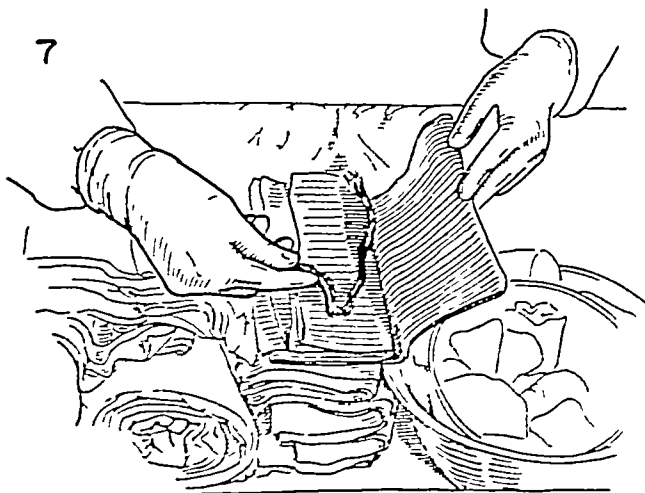
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ARRANGING NONABSORBABLE SUTURES

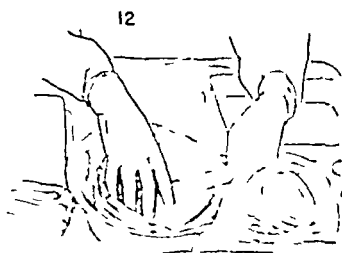
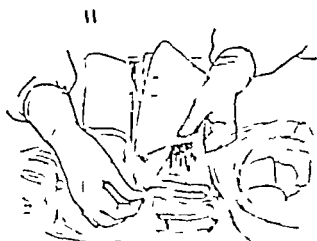
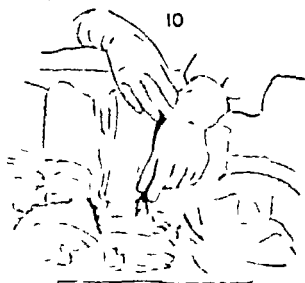
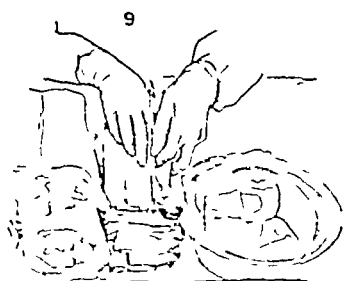
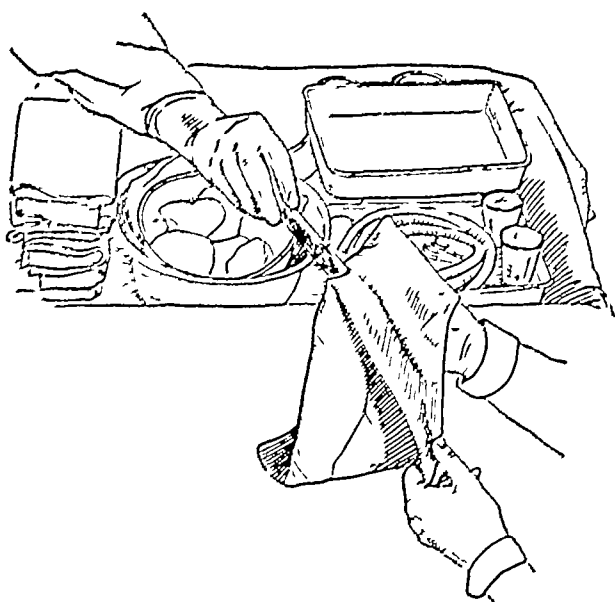


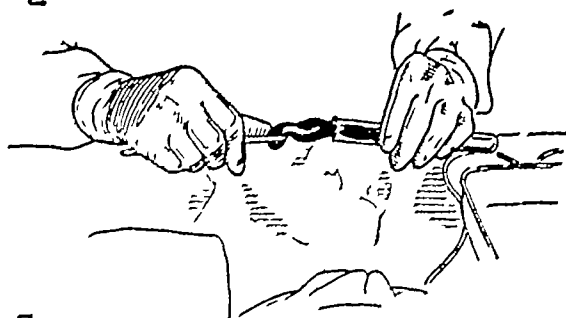
FIGURE 19

ARRANGING NONABSORBABLE SUTURES

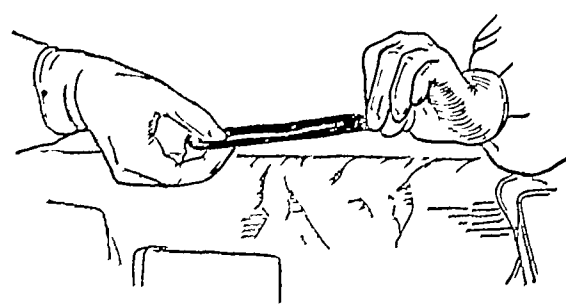
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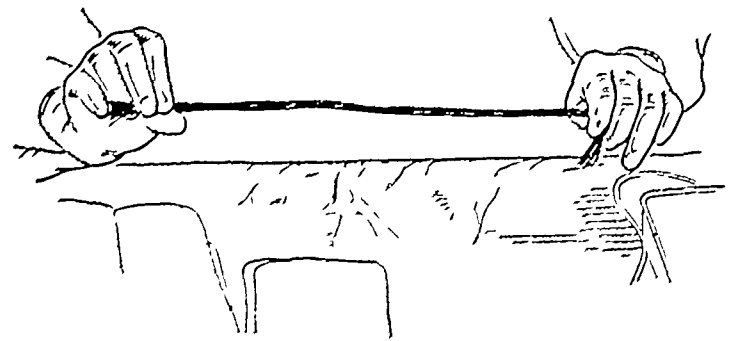
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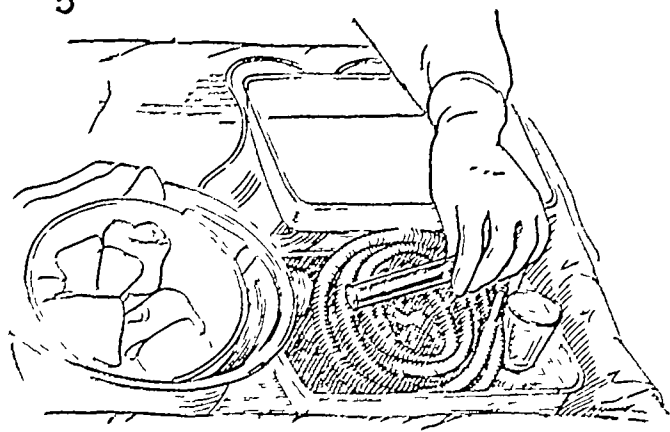
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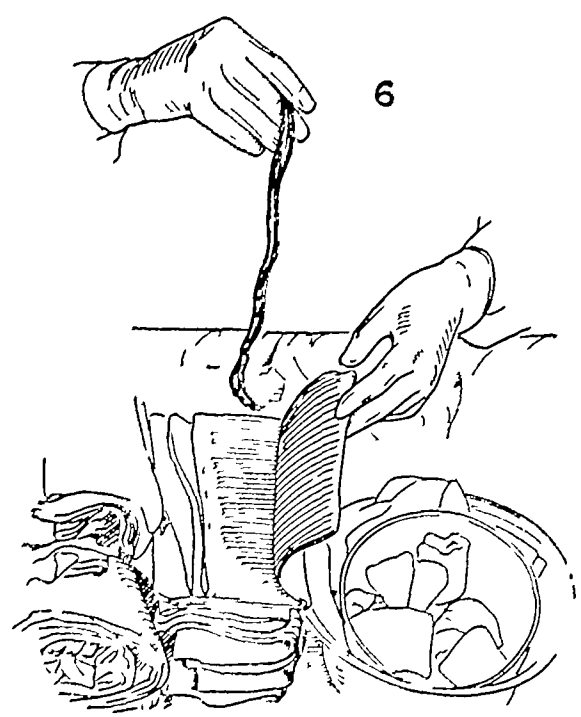
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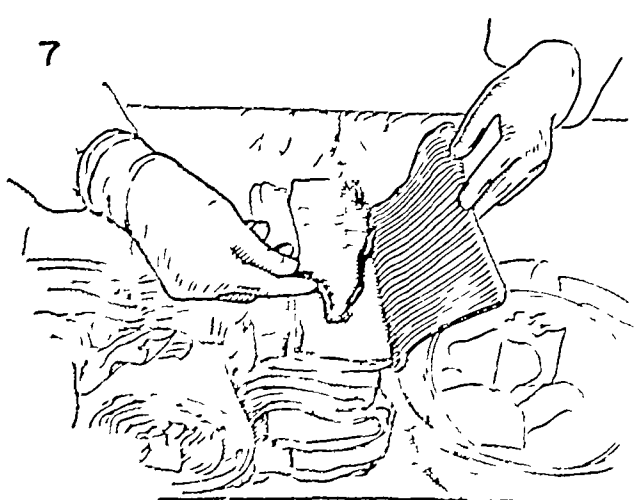
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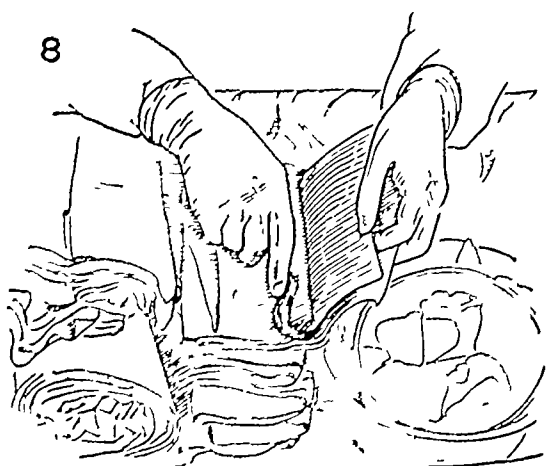
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ARRANGING NONABSORBABLE SUTURES

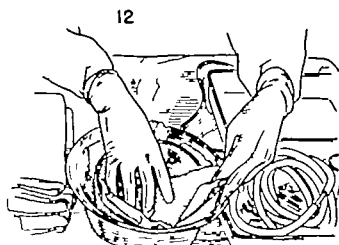
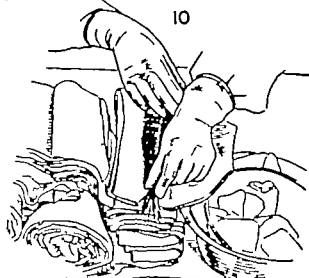
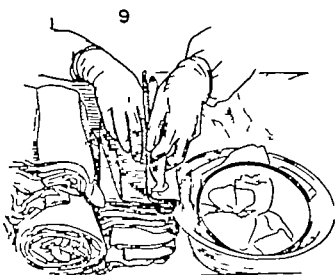


FIGURE 150

The packages containing gloves and suture material are unwrapped similarly and transferred to the sterile field.

The scrubbed nurse takes the gloves from the circulating nurse, figure 148, 7, and puts them in the front right hand corner of the table. If the wet glove technic is used, the gloves for the instrument man are removed from their envelope, figure 148, 3, and dropped into the glove basin, figure 148, 4.

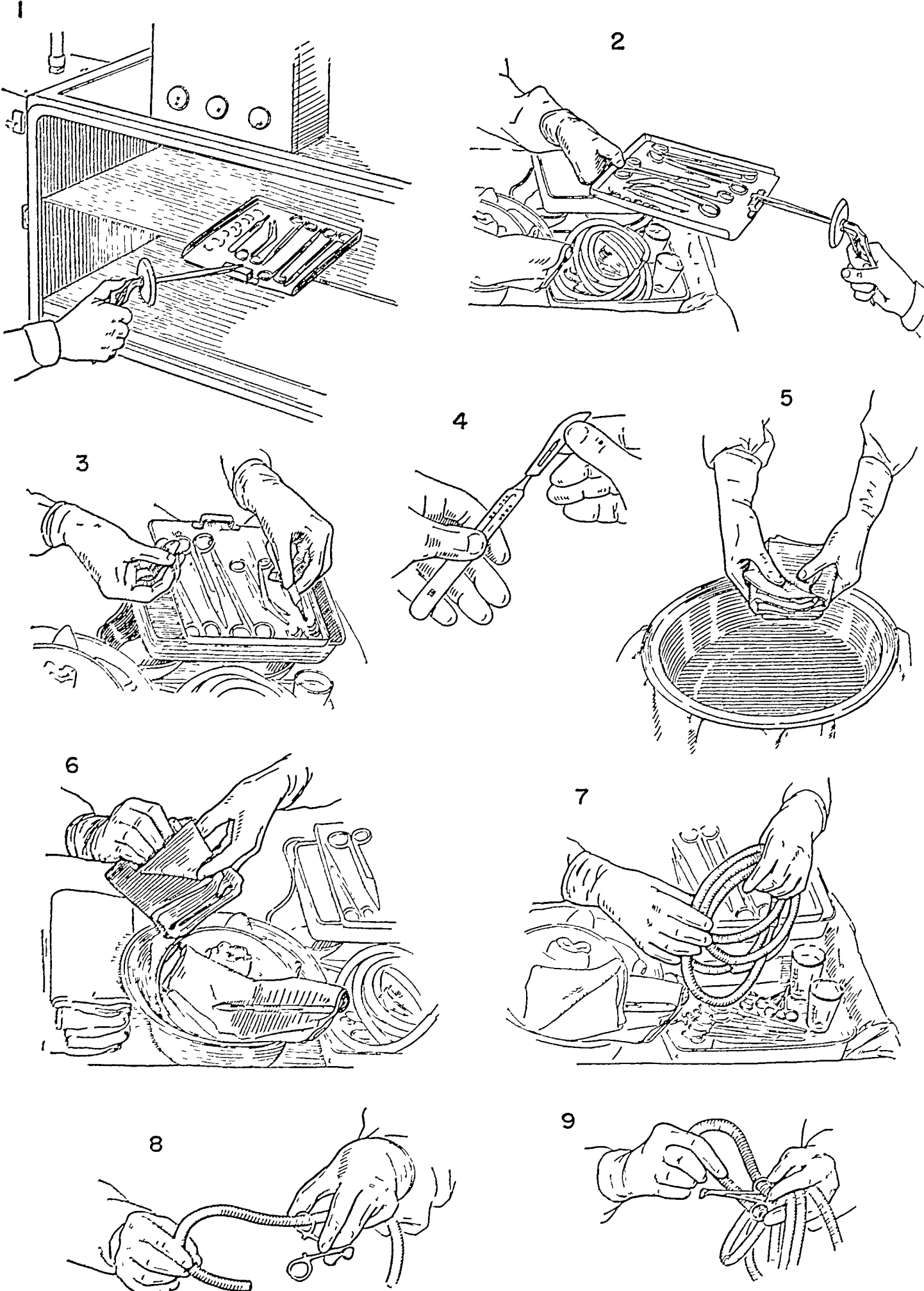
The waxed silk is prepared next, figure 149. The hank is pulled from the test tube, figure 149, 2, carefully untwisted, figure 149, 3, and pulled straight, figure 149, 4. The test tube is discarded into the aluminum pan which contains the nurse's kit, figure 149, 5. The hank is interleaved in the folds of a towel, figure 149, 6, 7, 8. The

individual threads are winnowed apart where they loop between folds, figure 150, 9. If the scrubbed nurse prefers to pull the silk from the towel by the ends, approximately 2.5 cm. are left protruding from the towel, figure 150, 10, 11. The towel containing the silk is then placed in the uppermost of the small basins, which is subsequently to serve as a waste basin at the operative field, figure 150, 12.

The circulating nurse meantime gets the aluminum tray containing the sterile cutting edge instruments from the dry heat sterilizer, figure 151, 1, and carries it to the sterile field with the sterile transfer forceps, figure 151, 2.

The scrubbed nurse fits the scalpel blade to the handle, figure 151, 3, 4, and places the

CUTTING INSTRUMENTS — TOWEL — SUCTION TUBING

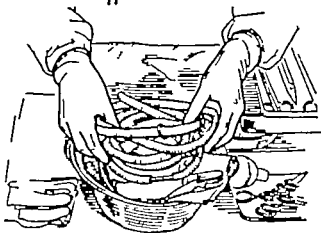


SUCTION TUBING — NEEDLE HOLDERS

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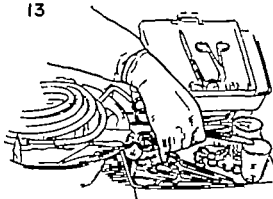
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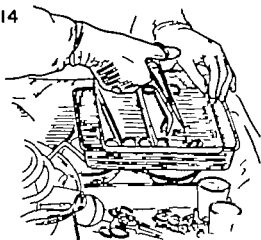
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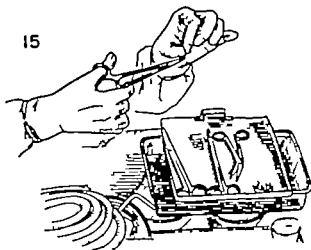
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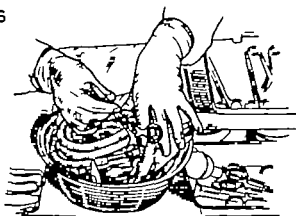
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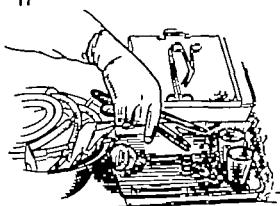
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NEEDLES — TOWEL CLIPS — SYRINGE

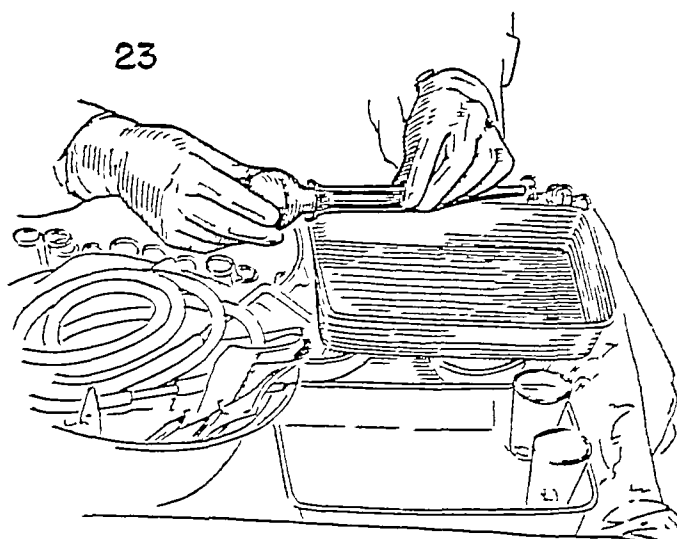
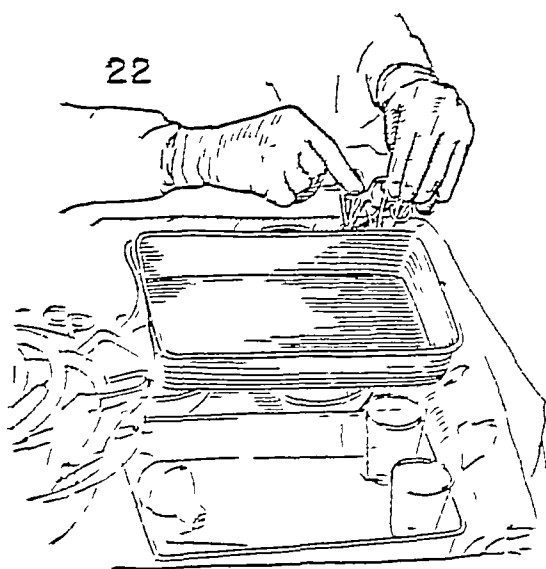
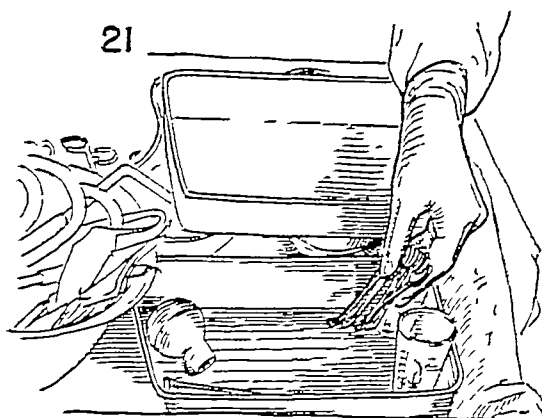
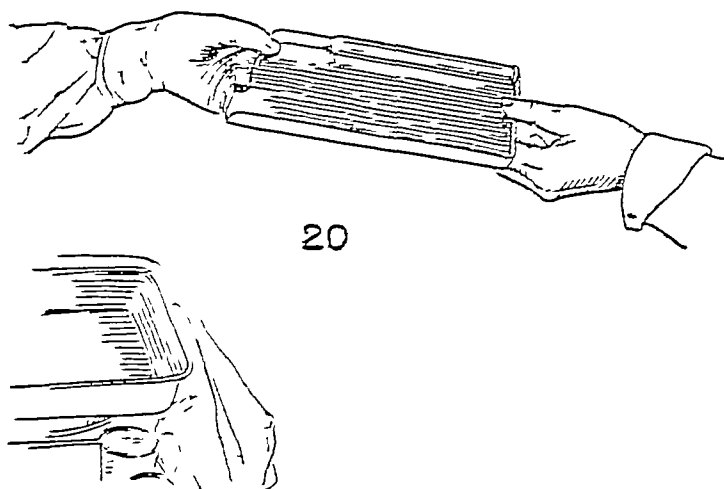
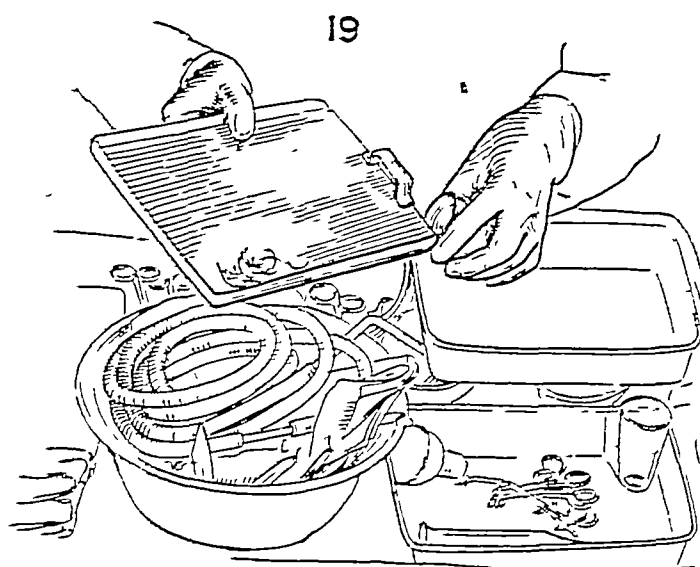
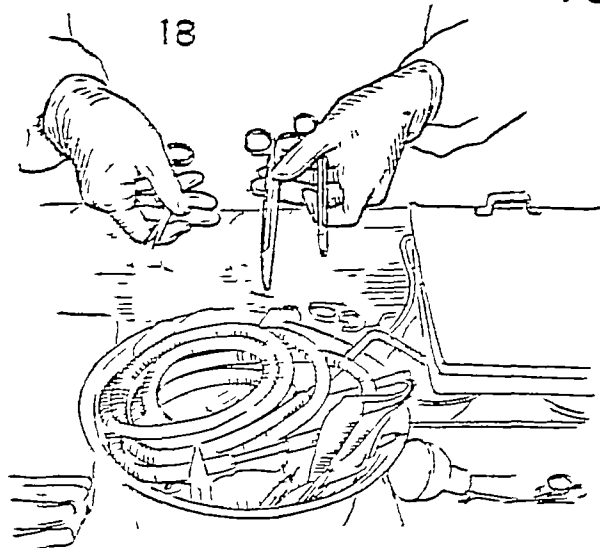


FIGURE 153

scalpel, handle-end uppermost, on the towel in which the silk has been interleaved, figure 151, 6 She selects the fanfolded towel, figure 96, 7 to 12, immerses it in the solution in the glove basin and wrings it out as dry as possible, figure 151, 5 This towel is placed on top of the scalpel, figure 151, 6

The rubber suction tubing is threaded through the rings of a towel clip, figure 151, 7, 8, 9, and the glass tip is inserted into the end of the rubber tubing, figure 152, 10 The coiled tubing is then placed on top of the moistened towel in the basin, figure 152, 11

The straight abdominal scissors are placed in the space between the folded towel and the edge of the small basin so that they stand upright, figure 152, 12.

The needle holders which are likely to be used early in the operation are loaded, figure 152, 13, 14, 15, and stood in the small basin along with the scissors, figure 152, 16 The remaining scissors and needle holders, figure 152, 17, are placed aside on the nurse's table, figure 153, 18, figure 157 Extra needles are poured into a medicine glass, figure 153, 19, and the aluminum tray is discarded to the circulating nurse, figure 153, 20 The towel clips are opened and arranged in the front left-hand corner of the table so that they are ready for use, figure 153, 21, 22.

The Asepto syringe is assembled, figure 153, 23, and placed on the nurse's table. If assembly is difficult, the tip of the bulb is moistened with 1:1000 aqueous Zephuran. The aluminum pan which contained the nurse's kit now serves as the waste pan on her table.

The straight needles threaded with silk are made ready for operation by unfolding the gauze strip into which they were basted, figure 154, 2, and pulling the sutures out. The sutures are most easily removed by pinching the gauze between the thumb and forefinger of the left hand, figure 154, 3

As each successive needle is pulled from the strip, pressure is exerted on the suture so that the longer end, figure 125, 8, can be grasped as it passes between the fingers and held so that the suture slips through the eye of the needle, shortening one leg to about 5 cm., figure 154, 4 The needles are then stuck into a folded towel which has been placed in the aluminum pan that will subsequently serve as a specimen basin, figure 154, 5 The basin prevents the needles from being inadvertently thrust through the sterile drapes into the unsterile table. Successive needles are stuck into the towel in an orderly manner, taking care that the strands are placed on top of each other. When these sutures are used at operation, the last needle to be stuck into the towel is removed first, thereby taking the uppermost suture from the pile without entangling the others. The towel is put aside in the front right hand corner, figure 154, 6

When surgical gut is to be used, the circulating nurse selects the proper tubes with the sterile transfer forceps and gives them to the scrubbed nurse, figure 155, 1 To open the tube, the nurse first identifies the scored mark about the glass tube and shakes the gut into the longer end, figure 155, 2, so that the strands will not be damaged when the tube is broken. The tube is placed between the folds of a towel, figure 155, 3, and grasped on either end with the thumbs located at either side of the scored mark. An attempt is then made to pull the tube apart longitudinally, as it is bent over the thumbs, figure 155, 4 When properly done, a clean break results, figure 155, 5 The surgical gut is shaken from the tube and unreeled carefully. One prong of the reel is broken off by bending it sharply forward and backward. The coiled gut is then slipped off the reel, figure 155, 6 Two fingers of the left hand are inserted into the coil and the free end of the suture

scalpel, handle-end uppermost, on the towel in which the silk has been interleaved, figure 151, 6 She selects the fanfolded towel, figure 96, 7 to 12, immerses it in the solution in the glove basin and wrings it out as dry as possible, figure 151, 5 This towel is placed on top of the scalpel, figure 151, 6

The rubber suction tubing is threaded through the rings of a towel clip, figure 151, 7, 8, 9, and the glass tip is inserted into the end of the rubber tubing, figure 152, 10 The coiled tubing is then placed on top of the moistened towel in the basin, figure 152, 11

The straight abdominal scissors are placed in the space between the folded towel and the edge of the small basin so that they stand upright, figure 152, 12.

The needle holders which are likely to be used early in the operation are loaded, figure 152, 13, 14, 15, and stood in the small basin along with the scissors, figure 152, 16 The remaining scissors and needle holders, figure 152, 17, are placed aside on the nurse's table, figure 153, 18, figure 157 Extra needles are poured into a medicine glass, figure 153, 19, and the aluminum tray is discarded to the circulating nurse, figure 153, 20 The towel clips are opened and arranged in the front left hand corner of the table so that they are ready for use, figure 153, 21, 22.

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NEEDLES — TOWEL CLIPS — SYRINGE

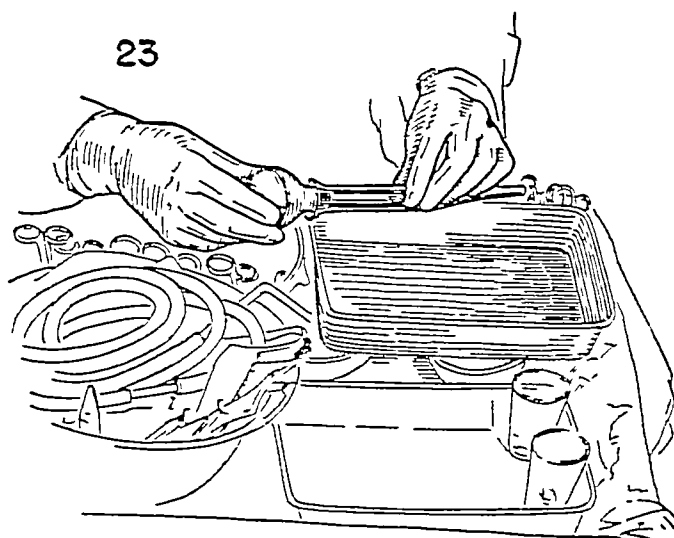
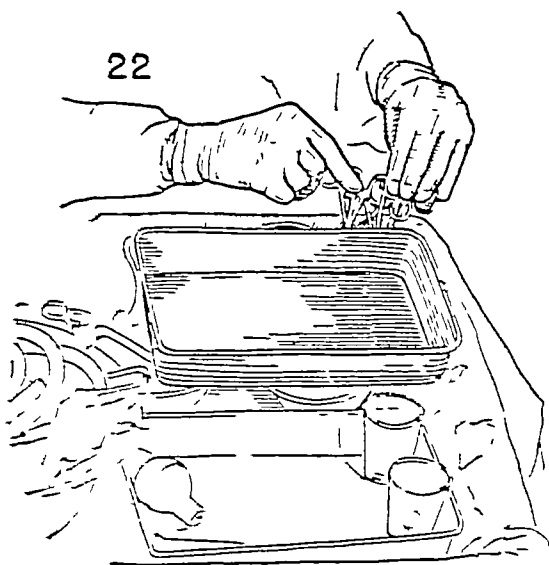
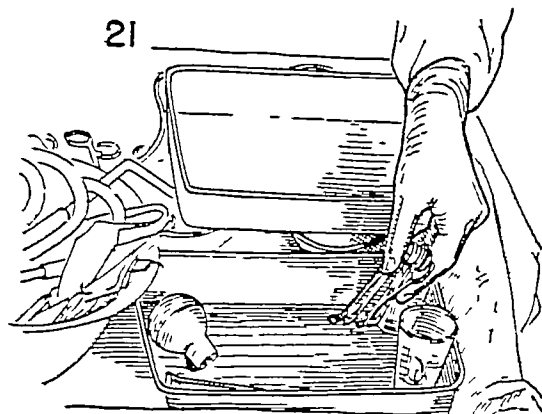
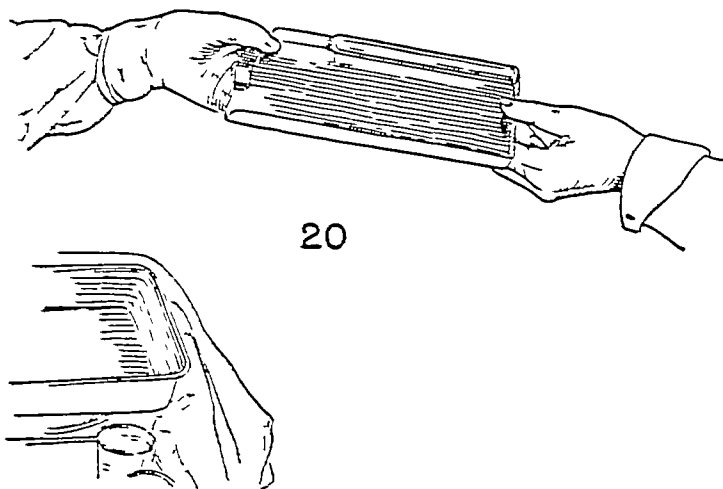
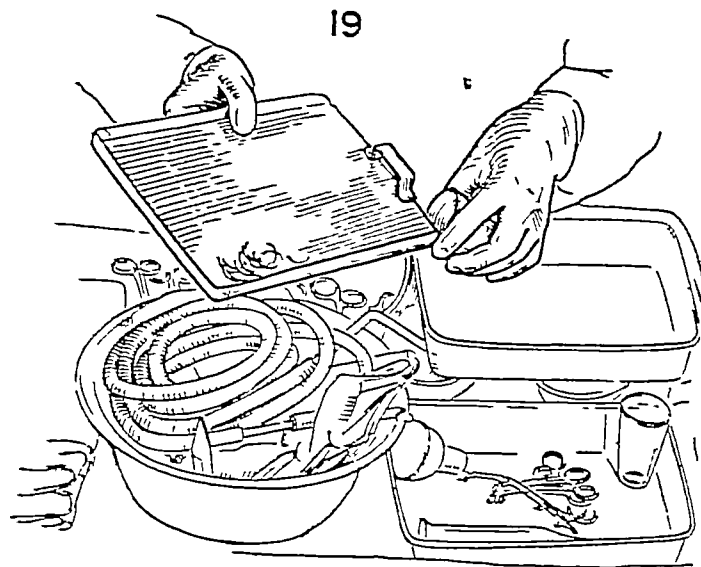
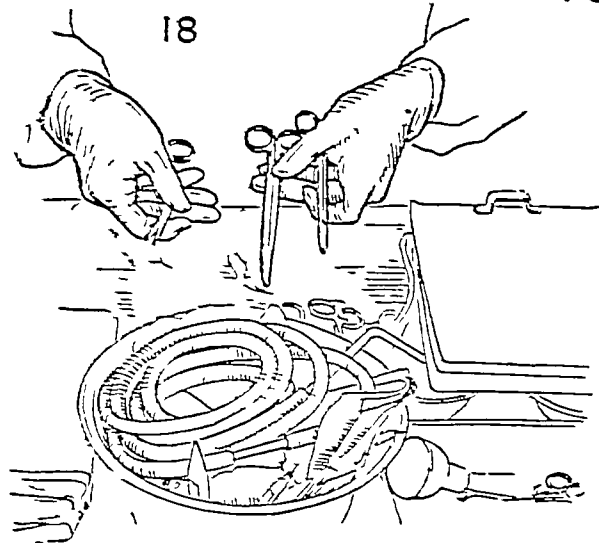


FIGURE 153

scalpel, handle-end uppermost, on the towel in which the silk has been interleaved, figure 151, 6 She selects the fanfolded towel, figure 96, 7 to 12, immerses it in the solution in the glove basin and wrings it out as dry as possible, figure 151, 5 This towel is placed on top of the scalpel, figure 151, 6

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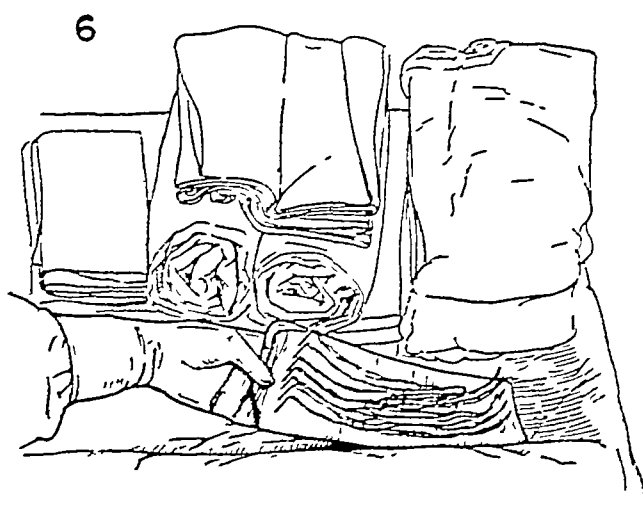
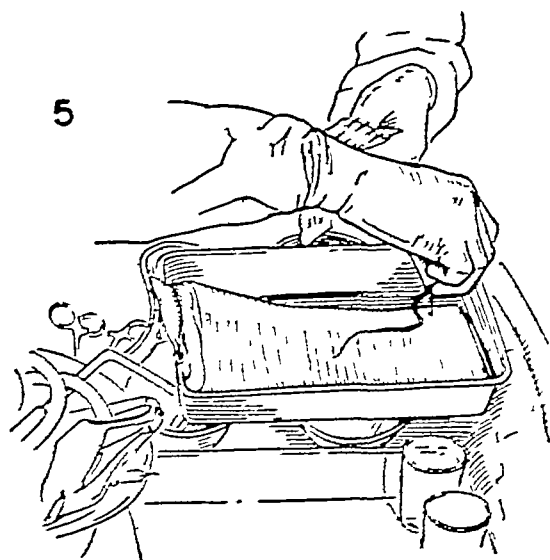
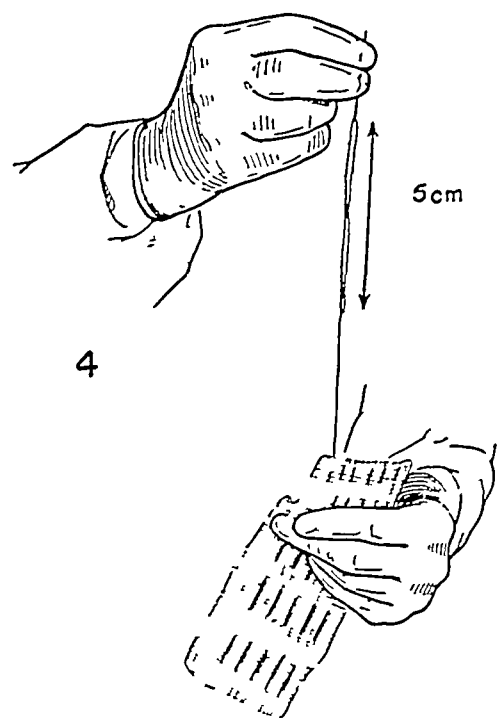
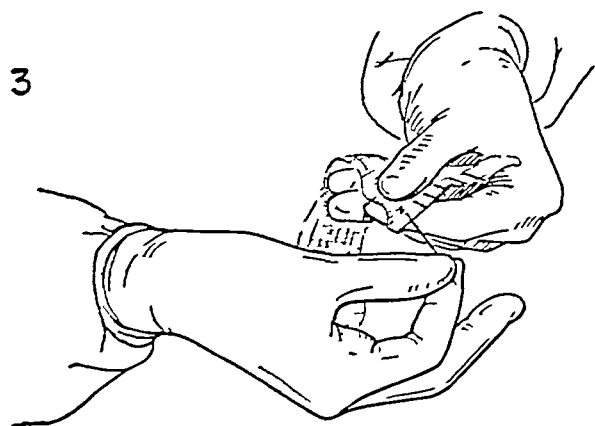
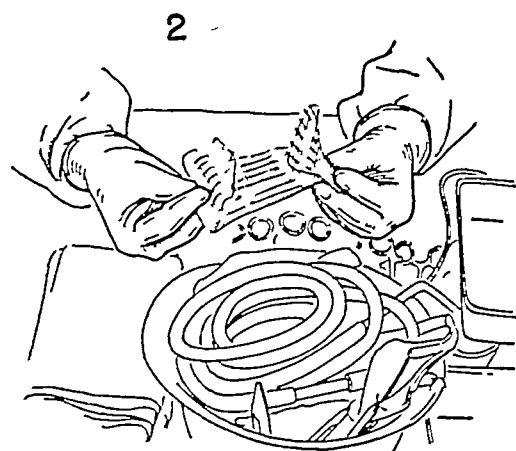
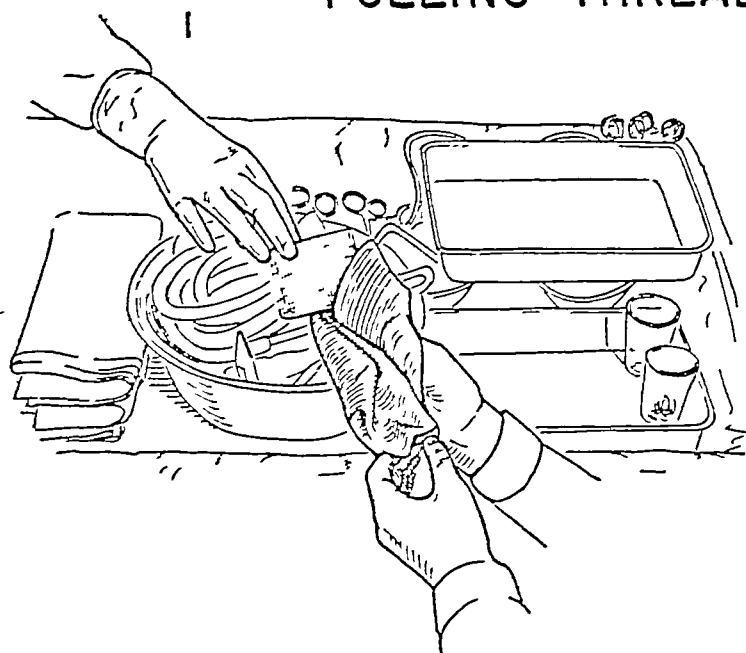
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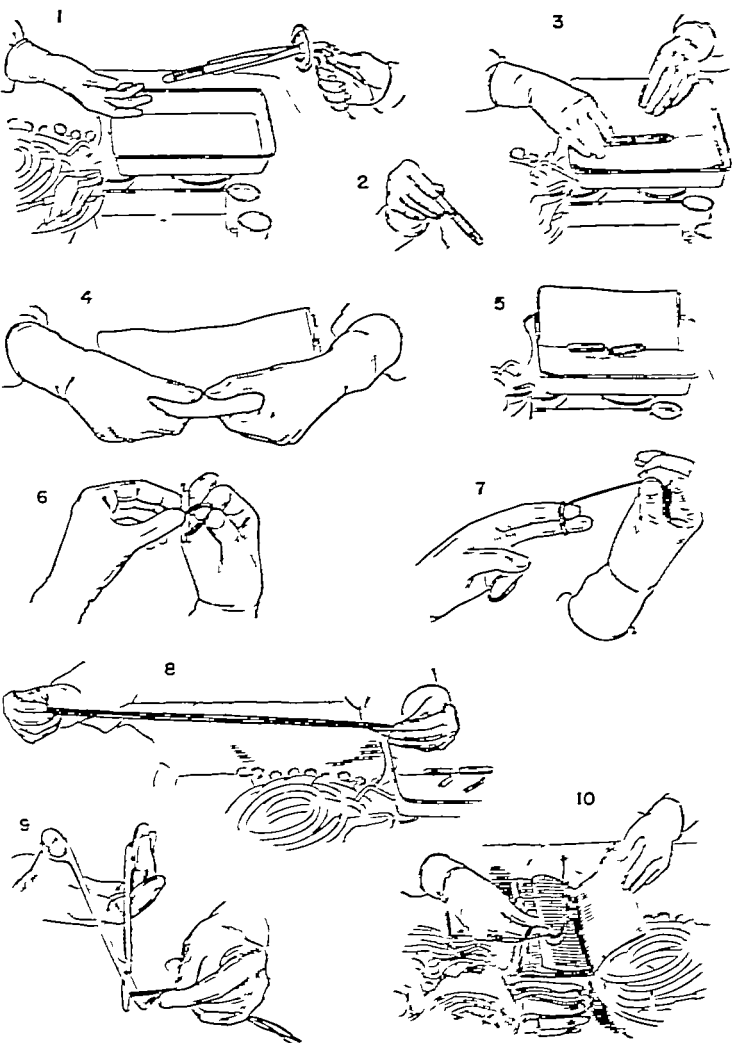
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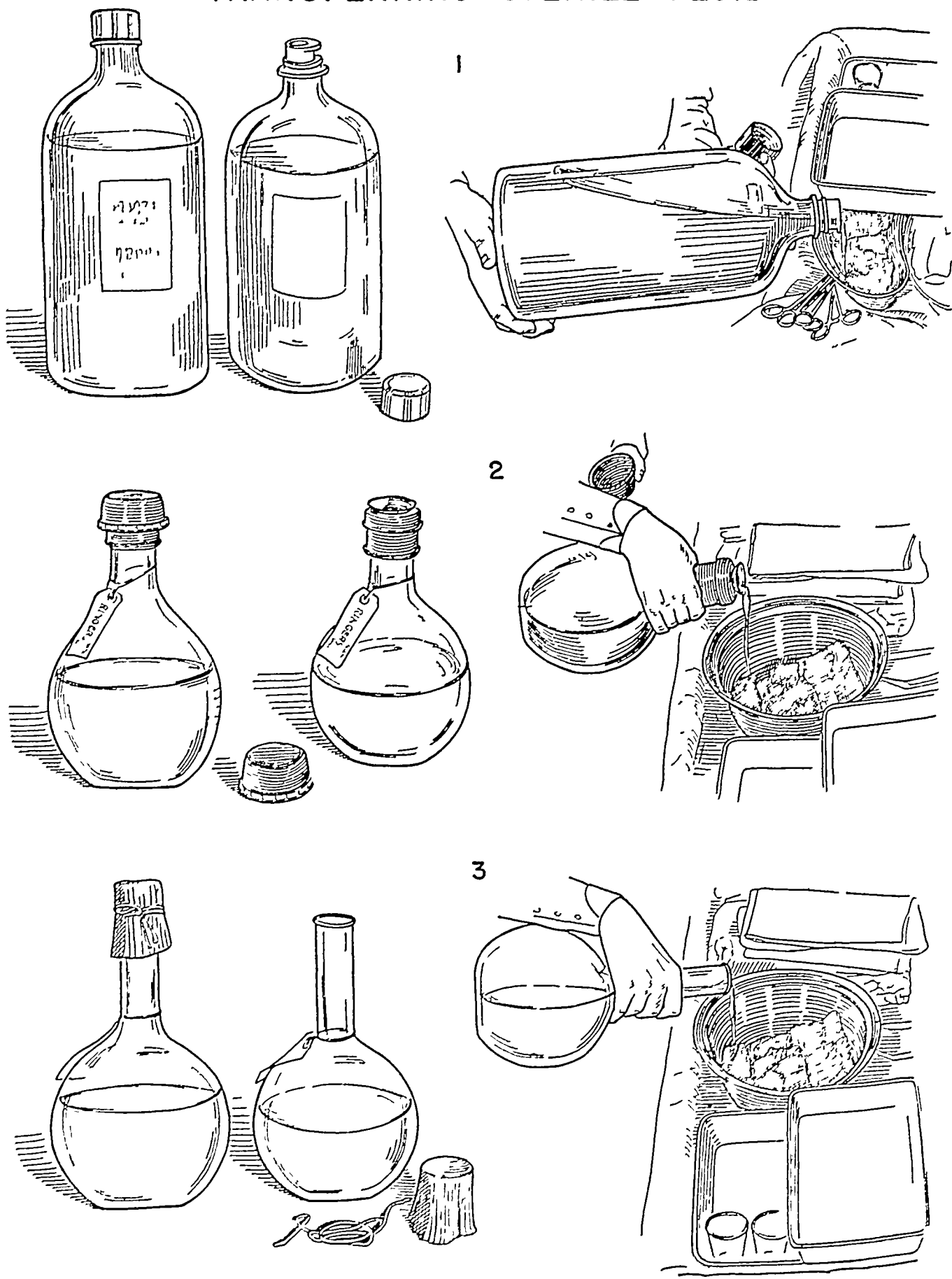
PULLING THREADED NEEDLES



READYING SURGICAL GUT



TRANSFERRING STERILE FLUID



ARRANGEMENT OF NURSE'S TABLE

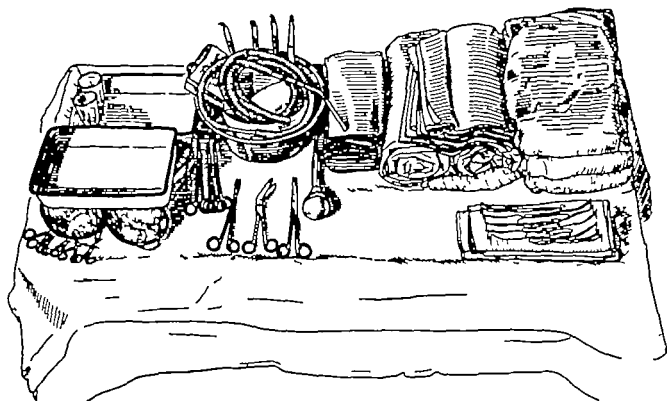


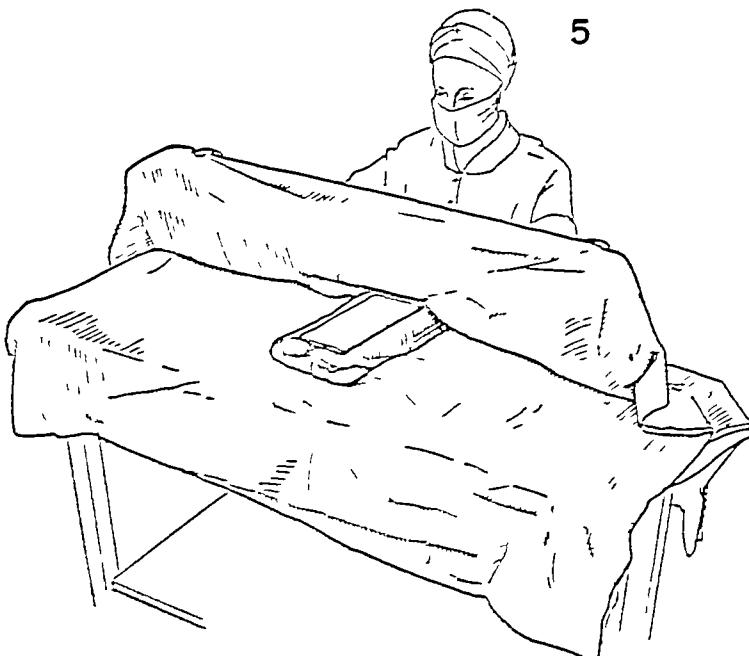
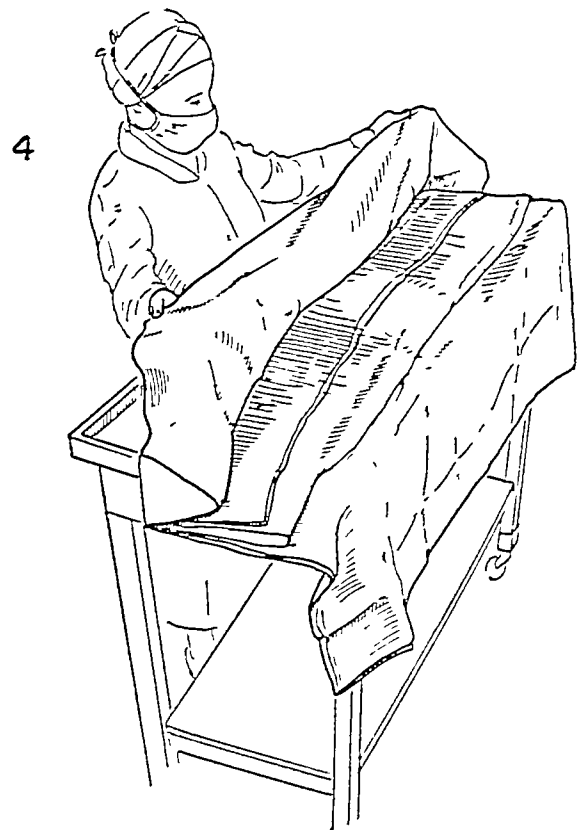
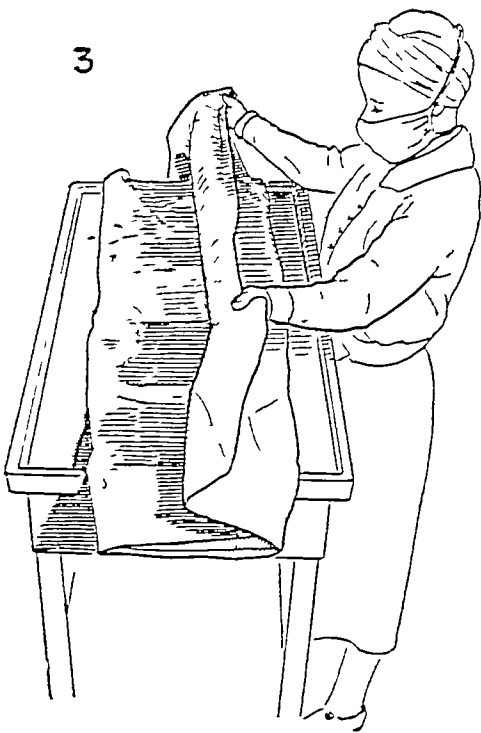
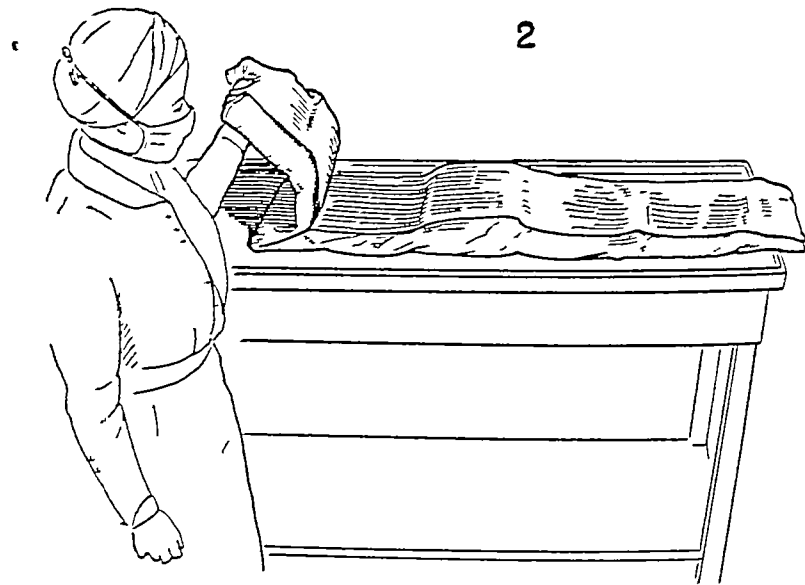
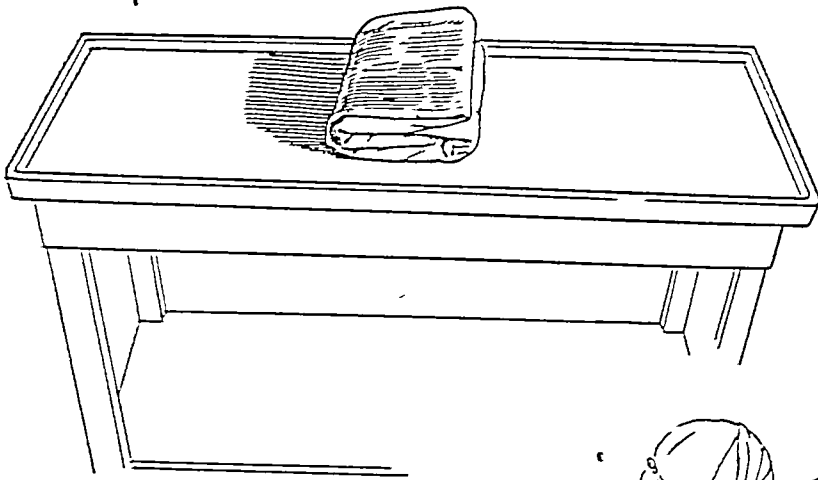
FIGURE 157

is grasped and the coil is unwound, figure 155, 7 The strand is doubled, pulled out straight and subjected to a light even pull to remove the bends, formed while it was coiled. Snarling and kinking are avoided by keeping the suture taut while it is being handled The suture is then looped into desired lengths, figure 155, 8, and cut, figure 155, 9 The pieces are interleaved in a towel moistened with alcohol, figure 155 10 Boilable gut is opened by a technic similar to that described To avoid burning fingers, tubes must be permitted to cool before an attempt is made to open them Because boilable gut is anhydrous, it is stiff and waxy and cannot be unreeled until pliability has been restored to the strands. This is most safely done by immersing the reels of gut in 70% ethyl alcohol for two or three minutes. The gut is then handled just like the nonboilable type and is stored in a towel moistened with 70% alcohol.

Seventy per cent alcohol and 1 1000 aqueous Zephiran are poured into respective kidney basins Although several technics are advocated for removing dirt and contaminating organisms from the lip of the bottle, the only safe technic is that depending upon the use of a bottle or flask with a pouring lip that is protected from contamination at all times. The Bell closure, figure 156, 1, or the "Pour-o-vac" closure, figure 156, 2, are safe simple closures for dispensing sterile fluids in the operating room. They can be resealed and opened repeatedly without danger of contamination When used carefully, the paper flask-hood also provides a safe means of transferring sterile fluid to the operative field, figure 156, 3 The traditional technic of pouring a quantity of fluid over the lip is sloppy and bacteriologically ineffectual

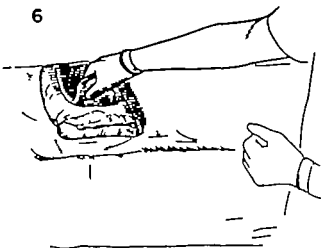
While the scrubbed nurse arranges her table, figure 157, the circulating nurse

OPENING INSTRUMENT TABLE KIT

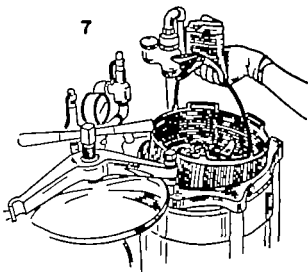


TECHNIC FOR INSTRUMENT MAN

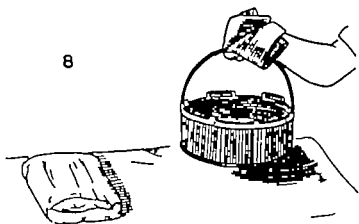
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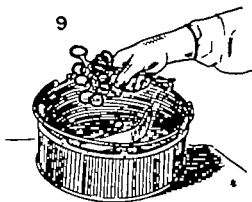
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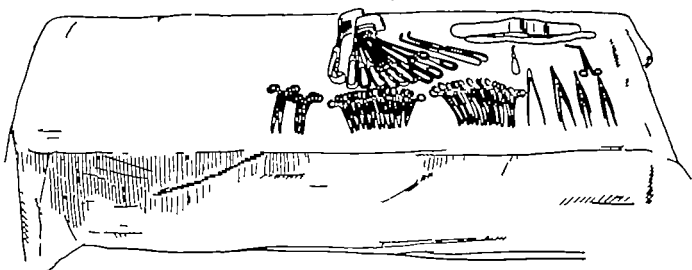
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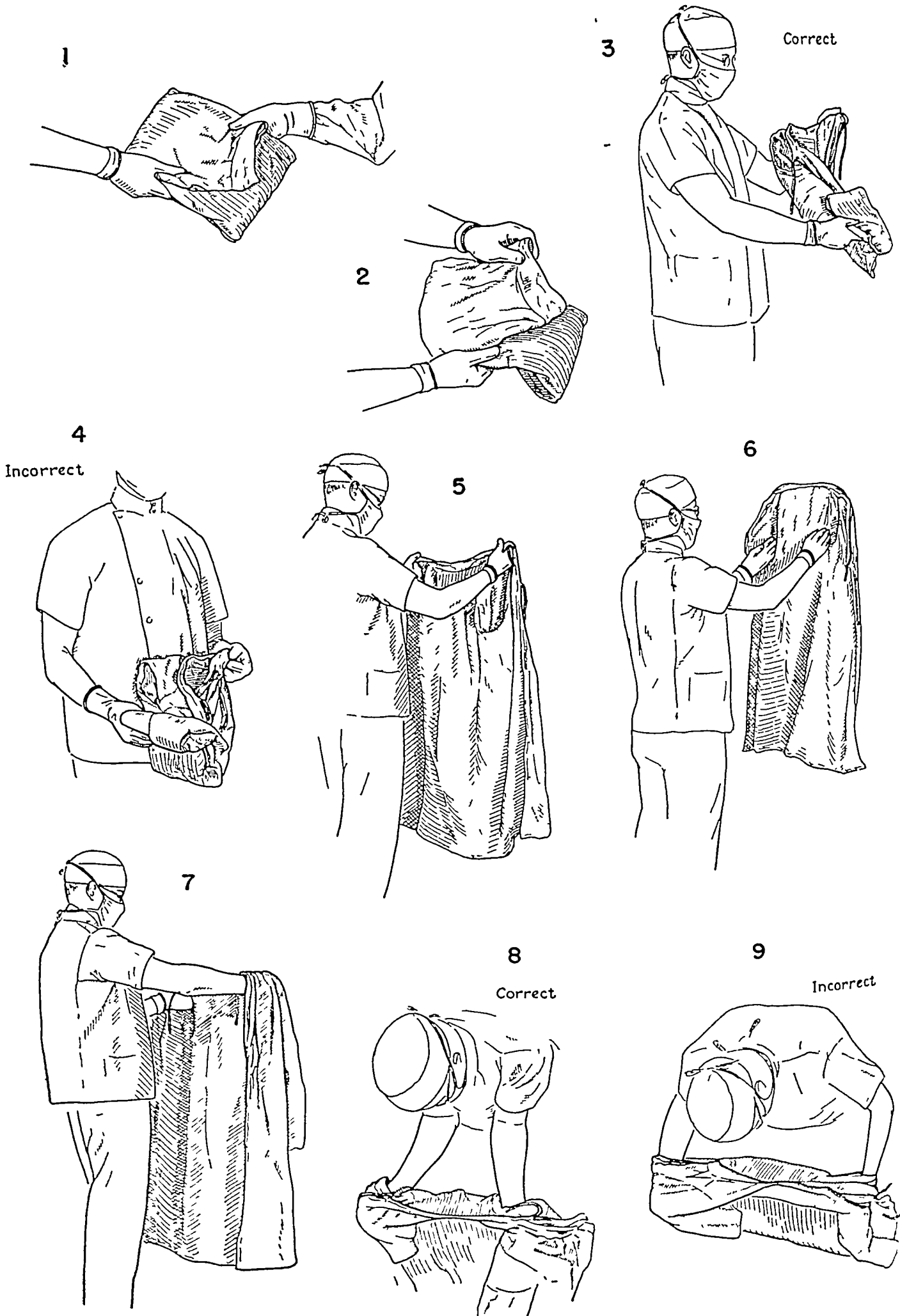
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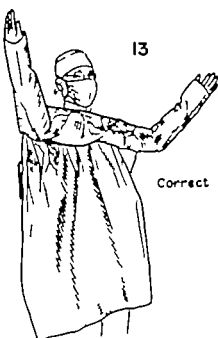
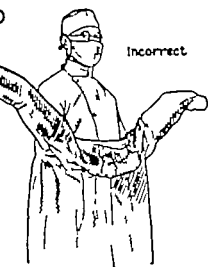
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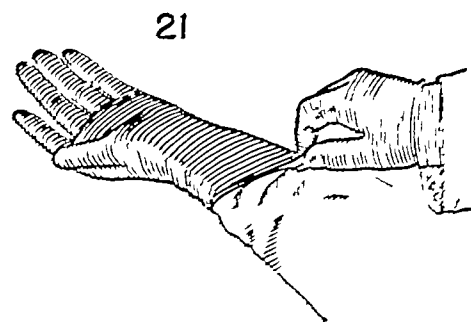
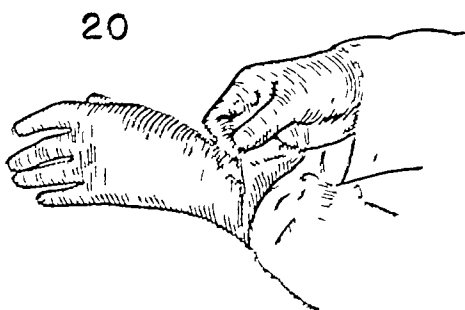
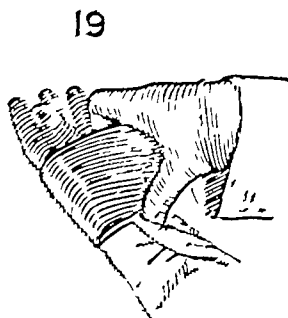
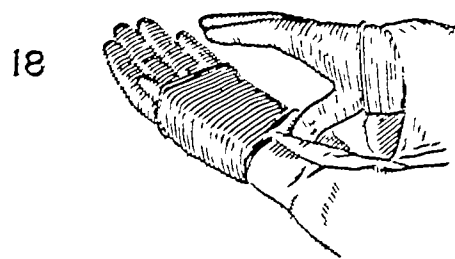
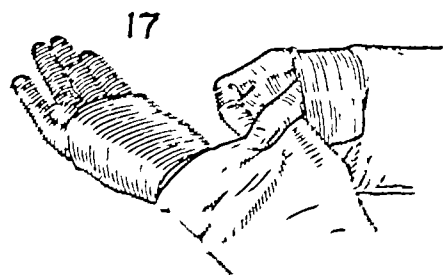
DONNING A GOWN



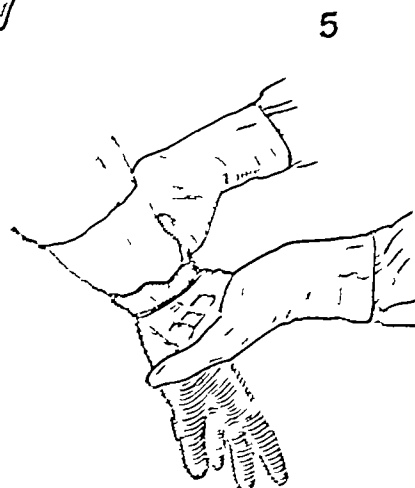
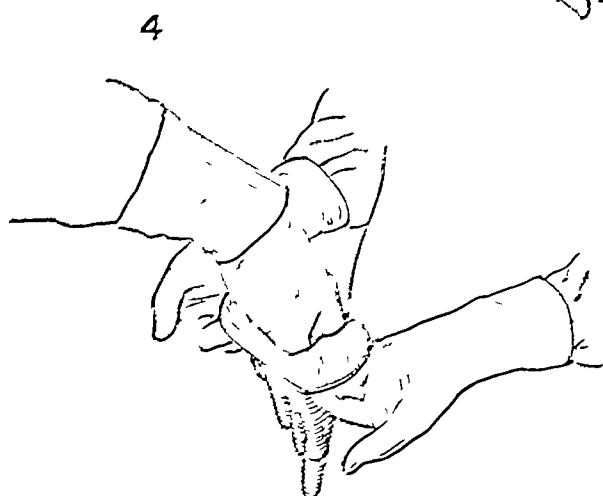
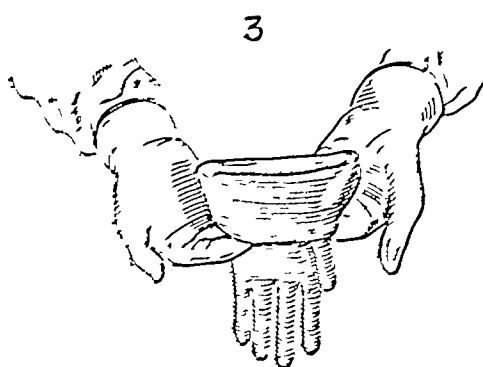
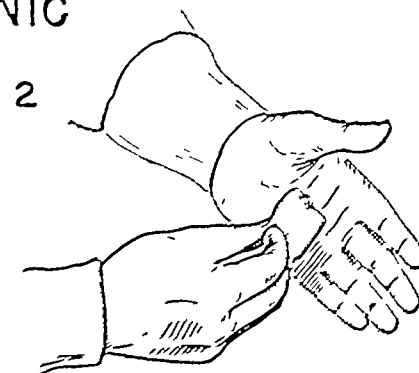
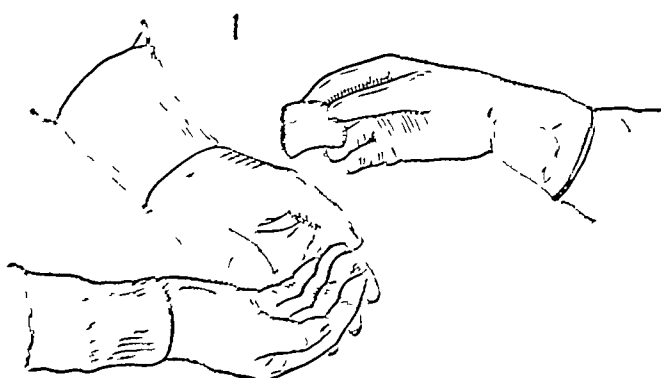
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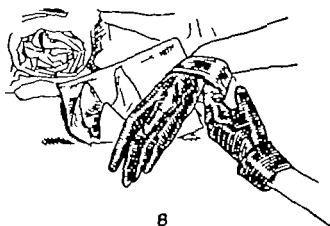
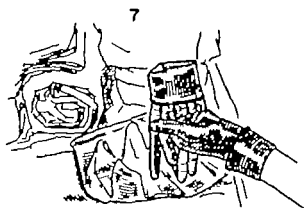
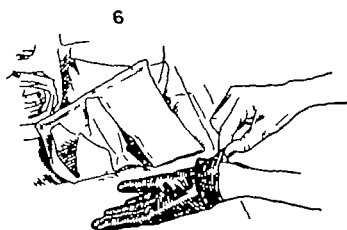
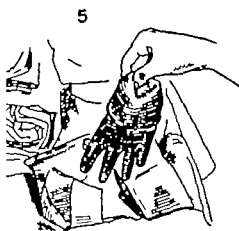
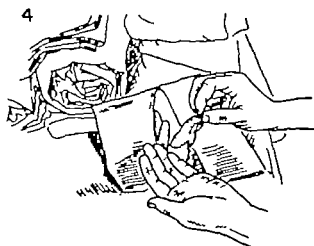
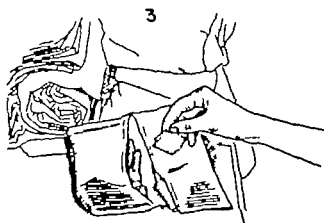
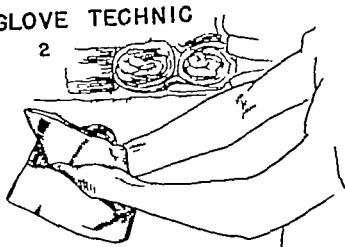
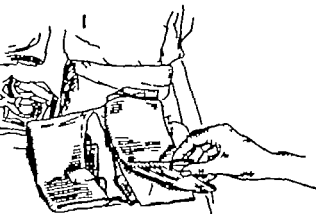
DONNING A GOWN



DRY GLOVE TECHNIC



ALTERNATE DRY GLOVE TECHNIC



drapes the instrument table. The instrument kit is placed in the center of the table, figure 158, 1. The library tie is opened and the tape removed. The ends of the sheet are unfolded, figure 158, 2, and the table is draped by a technic similar to that used in opening the large package of dry goods, figure 158, 3, 4, 5. The instrument man puts on gloves, picks up the towel from the center of the instrument table, figure 159, 6, and gets his bucket of sterile instruments from the sterilizer, using the towel to protect his hands, should the bail of the bucket be hot, figure 159, 6, 7. The bucket is placed on one corner of the table and the towel is discarded. He dons the gown from the center of the table, and arranges the instruments for ready selection, figure 159, 9, 10.

The gown is folded so that the collar presents, figure 86, 10. It is passed collar uppermost and is accepted in the right hand, figure 160, 1. The collar is grasped in the left hand and the gown is unfolded at arm's length, figure 160, 2, 3, to avoid contamination against the front of the scrub suit, figure 160, 4. A wise precaution is to face a sterile field before unfolding the gown so that there is little chance for someone to brush against it. After the gown has been unfolded, the ends of the collar are grasped in either hand and it is shaken thoroughly to loosen the sleeves and to open the armholes so that they can be identified readily, figure 160, 5. The best technic is to toss the gown into the air, figure 160, 6, and to catch it by thrusting the extended hands into the sleeves, figure 160, 7. The arms are then adducted across the chest and rotated outward, figure 160, 8. In this position, the arms slide into the sleeves readily. When the fingers reach the region of the elbows of the sleeves, the elbows are extended and the arms abducted, figure 161, 13, and the hands slip the remainder of the way through the sleeves and cuffs. If the sleeve is stuck

together, it may be necessary to wiggle the fingers to crawl down the inside of the sleeve. Usually, however, it is possible to slip into the gown with no assistance. At this stage, the circulating nurse grasps the back corners of the collar, pulls the gown upward and backward over the shoulders, figure 161, 14, and ties the tapes, figure 161, 15. She then smooths the gown by grasping the bottom hem and jerking it downward, figure 161, 16.

A common fault which leaves one stranded with the sleeves caught on the forearms is to attempt to insert the arms into the sleeves with the arms internally rotated and abducted, figure 160, 9. The result is contamination of the bosom of the gown against the front of the scrub suit, figure 161, 10. Technics which depend upon the insertion of the arms into the sleeves one at a time are dangerous because contamination is too likely. The edges of the armholes may be contaminated by dragging them across the front of the scrub suit, figure 161, 11. The clean hand and arm are subsequently contaminated when inserted into this sleeve. Another potential source of contamination is to drag the clean hand across the chin while inserting the opposite hand into the sleeve of the gown, figure 161, 12.

Finally, the cuff of the gown is inserted into the glove by folding the excess as a pleat across the front of the wrist, figure 162, 17, and holding it with the tip of the thumb, figure 162, 18, as the fingers catch the glove, figure 162, 19, and roll it over the cuff of the gown, figure 162, 20, 21.

There are two acceptable technics for putting on dry gloves. The safest technic depends upon the use of an elastic cuff on the gown so that it hugs the wrist and does not slip down to contaminate the glove, and assistance to hold the glove open while the hand is being inserted. The hands and arms are dried on a sterile towel before the

gown is put on. After the gown has been donned, the nurse passes the sponge containing the talcum, figure 162, 1, so that the hands can be powdered, figure 162, 2. She then slips her fingers beneath the everted cuff of an appropriate glove, figure 162, 3, and stretches the cuff and palm open between her hands so that the ungloved hand can be inserted readily, figure 162, 4. She then guides the cuff upward over the sleeve before she releases the tension, figure 162, 5. In the other technic illustrated, care must be taken to select slightly oversized gloves so that they can be put on easily. Otherwise, contamination is inevitable. The gloves are packaged as described in figures 120 and 121 so that each envelope contains a sterile towel and a gauze sponge loaded with talcum. The scrubbed nurse opens the envelope and places it on the corner of the table, figure 163, 1, presenting the sterile towel. The hands and arms are dried, care being taken to dry the arms last to avoid contamination, figure 163, 2. The towel is discarded into the kick pail. The sponge containing the talcum is picked up, figure 163, 3, and used as a puff to powder the hands, figure 163, 4. One of the gloves is grasped by the everted cuff, figure 163, 5, and the fingers of the opposite hand are snuated into it, figure 163, 6. The opposite glove is picked up by slipping the everted fingers behind the everted cuff, figure 163, 7, to hold the glove while the other hand is inserted, figure 163, 8. A gown is then put on as described in figure 160. If the cuffs of the gown are made of stockinette, the gown may be put on before the gloves because the stockinette snugs the sleeves to the wrist and prevents its sliding down over the gloves.

REPARATION OF THE PATIENT FOR OPERATION

In the operating room there are five general principles which must be observed

- 1 The patient must be adequately restrained to avoid injury while semiconscious, as well as to prevent accidental contamination of the operative field.

- 2 The patient must be positioned to afford maximum exposure of the operative site but this must not be done by handicapping the anesthetist, who must be given adequate access to perform his duties.

- 3 The patient's clothing and bedding must be folded to expose the region to be operated upon and must be fixed so that they cannot come loose during the operation and inadvertently contaminate the field.

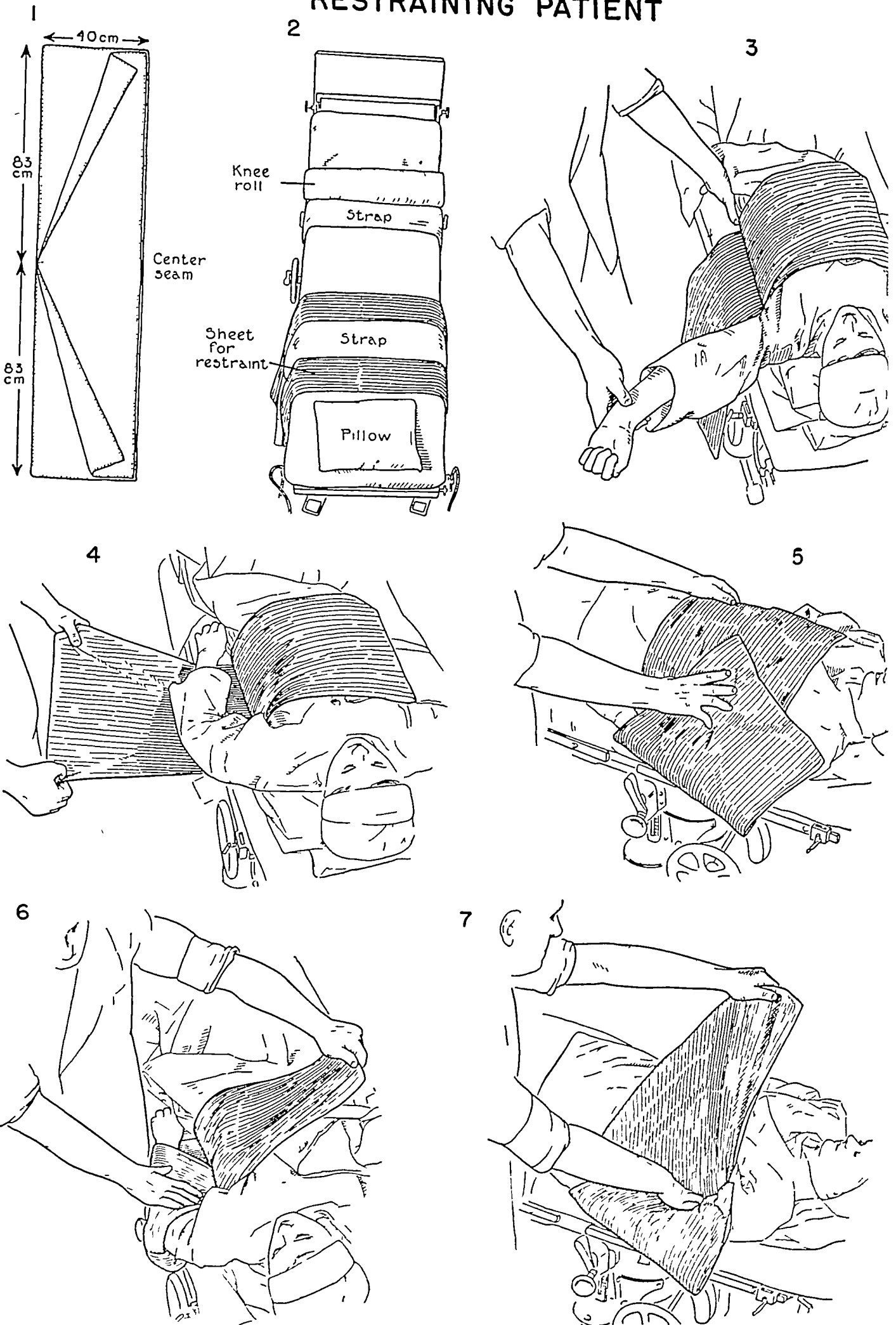
- 4 Illumination must be arranged so that the surgeon and his assistants can see.

- 5 Some provision must be made for a flat working surface where supplies and instruments can be spread out for ready selection.

The only opportunity for controlling these factors presents itself when the patient is first brought into the operating room. The table must be located with an eye to taking maximum advantage of the fixed lighting equipment. The patient must be positioned securely with the preferences of the surgeon in mind as well as with some consideration for the surgeon's height. Adjustments which must be made during the course of an operation indicate poor planning and laxity or ill advised haste on the part of the team.

Of the many ways of restraining the patient, one of the most effective is illustrated in figure 164. A four tailed restraint sheet, made as indicated in figure 164, 1, is placed transversely across the operating table so that its upper border lies at the level of the patient's axillas, figure 164, 2. A ten centimeter webbing strap is placed across the center of the sheet and a thin

RESTRAINING PATIENT



RESTRAINING PATIENT

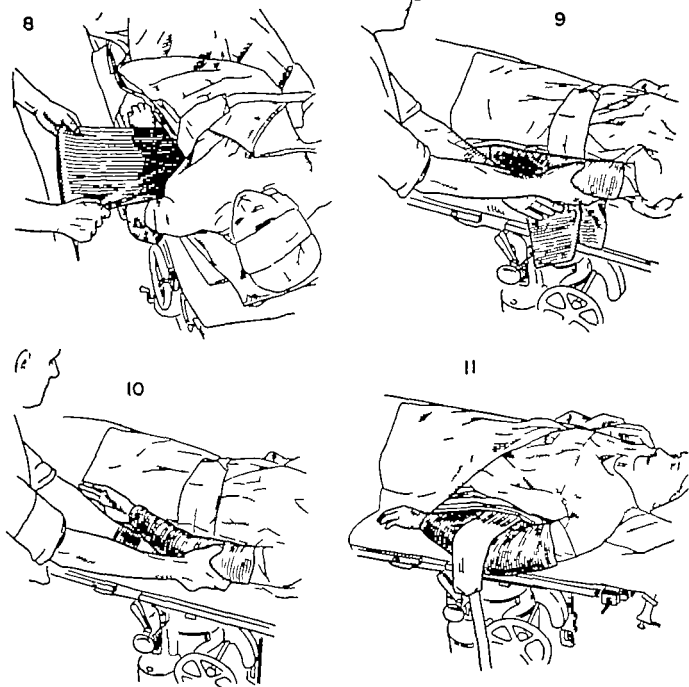
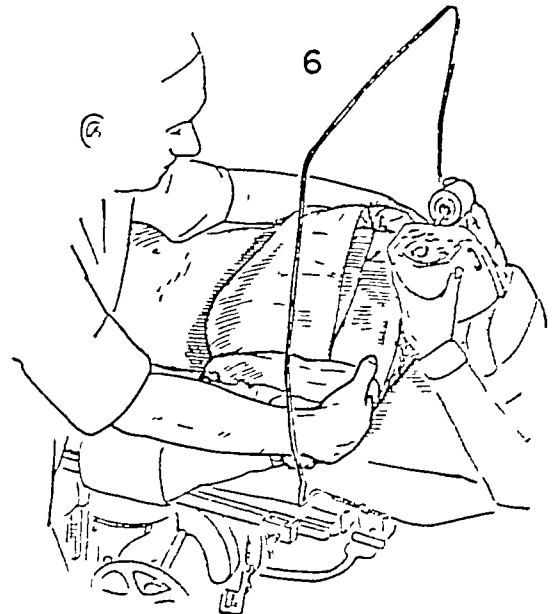
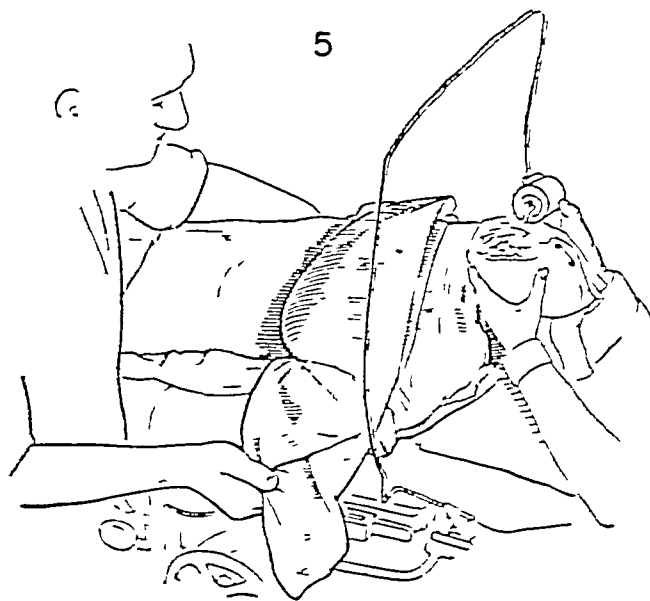
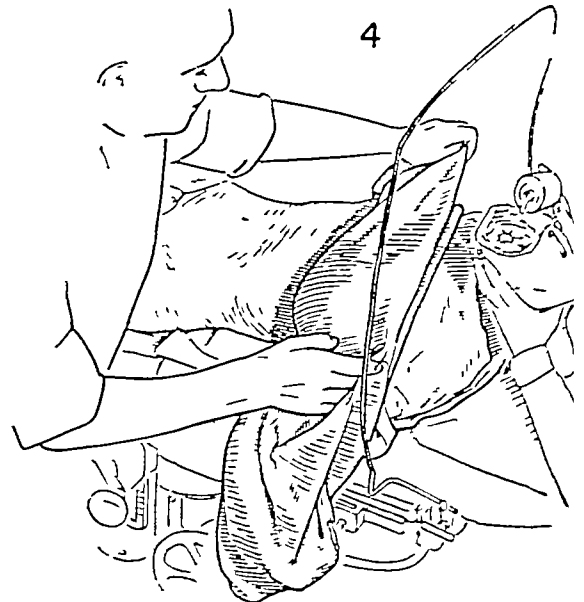
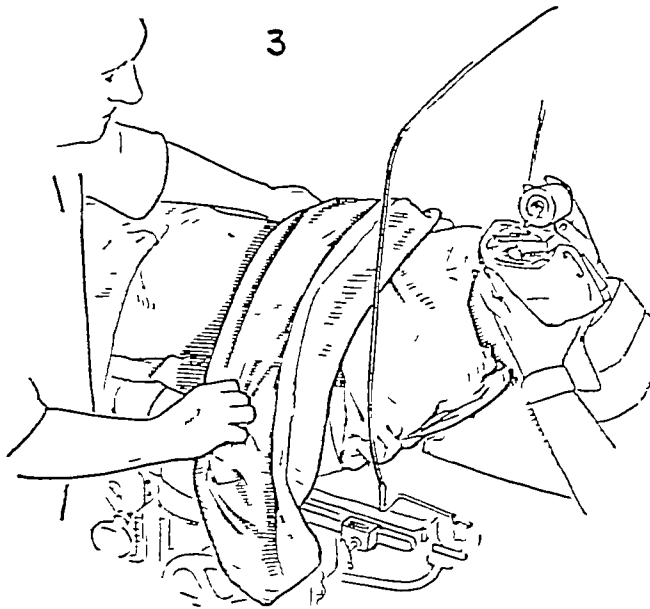
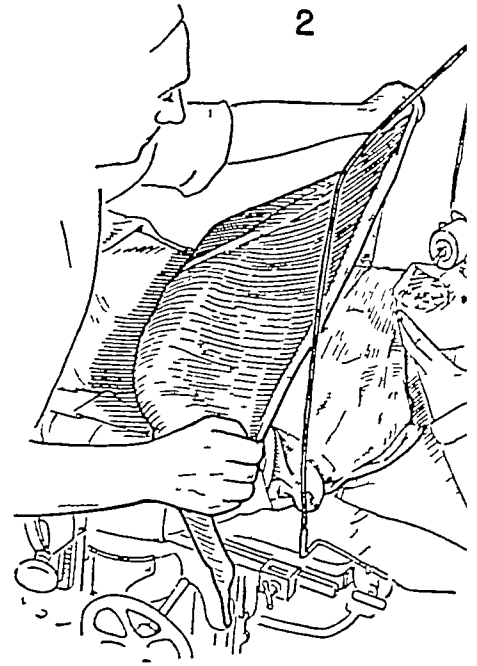
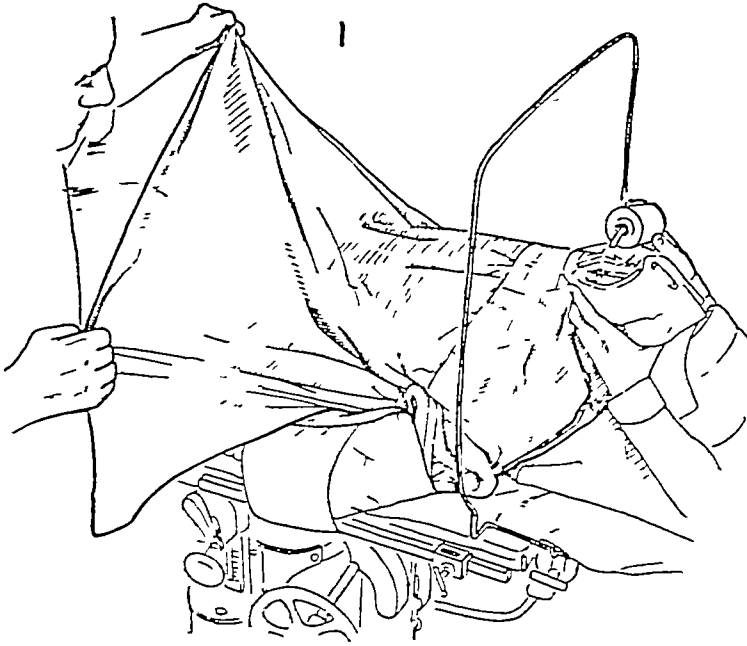


FIGURE 165

cotton blanket, folded longitudinally, covers all. The strap and one of the tails is thrown across the patient's chest, figure 164, 3, and the arm is placed comfortably at the patient's side, figure 164, 4. The bottom tail is then brought up and tucked beneath the patient, figure 164, 5, 6, 7, and the upper tail is pulled taut, figure 165, 8, and tucked beneath the arm, figure 165, 9, 10. The strap is then turned down over the arm, figure 165, 11. The opposite arm is prepared in a similar fashion and the two ends

of the strap are buckled snugly beneath the table. A ten centimeter roll is placed beneath the knees to flex the thighs and relax the abdomen. Another strap is buckled across the lower thighs, effectively restraining the most difficult patient. Neither strap need be pulled tightly so that the most apprehensive patient is not alarmed. A sphygmomanometer cuff and stethoscope may be adjusted to either arm before the restraining sheet is applied. If parenteral therapy is likely to be necessary, the venipuncture is

EXPOSING OPERATIVE SITE



best done at this stage when the great saphenous vein is accessible

The blankets and the patient's bed clothing are arranged for a laparotomy as shown in figure 166. The blankets are turned down over the patient's thighs to expose the whole of the abdomen. The skirt of the hospital gown is straightened, figure 166, 1, and folded upward, figure 166, 2. A second fold is then made to expose the lower chest, figure 166, 3, 4. The folds are smoothed, figure 166, 5, and the ends of the gown are turned upward at right angles and tucked beneath the shoulders, figure 166, 6, fixing the gown so that it will not subsequently slide downward.

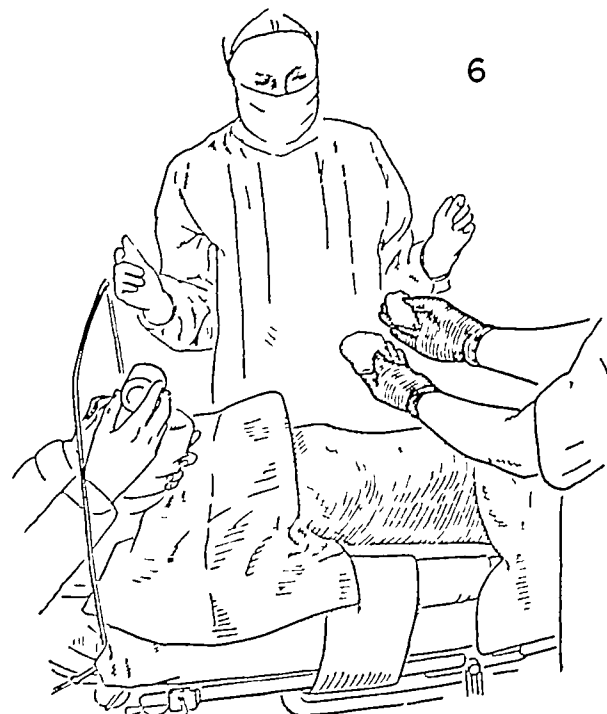
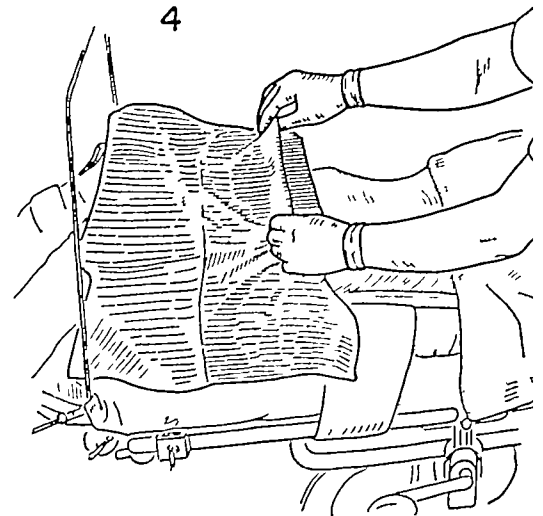
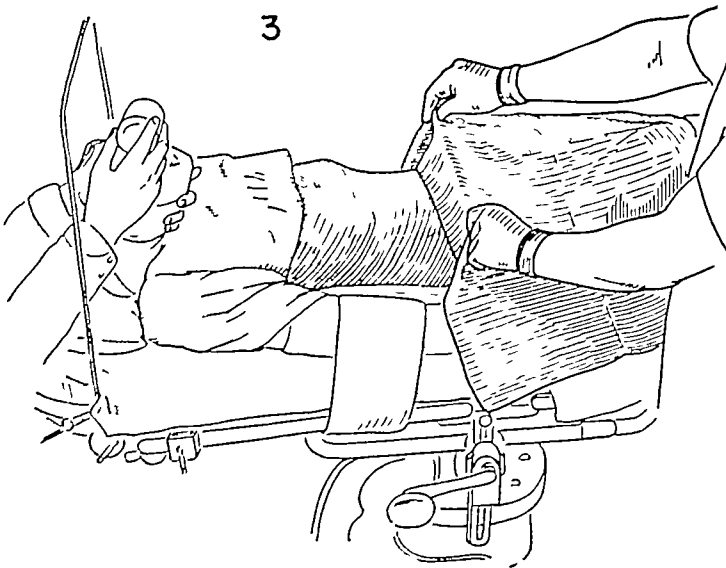
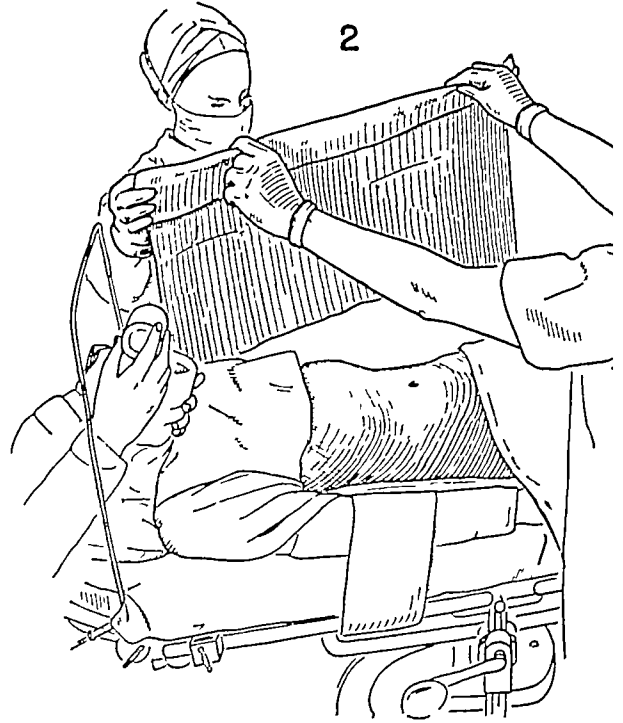
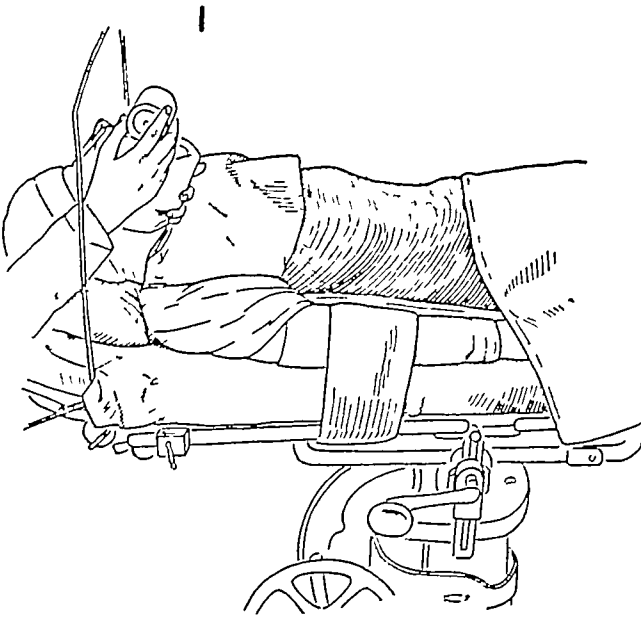
Only after the patient has been positioned properly, figure 167, 1, the lighting arranged, and the anesthetist's exposure assured, should preparation be made to disinfect the skin of the operative field. The responsibility for satisfactory disinfection must be relegated to the first assistant or someone of equal competence who understands that the magic of skin disinfection lies in the skill with which it is mechanically cleansed. Whether or not gloves are worn while disinfecting the skin is a matter for individual choice. Long experience with the technic where bare hands have been used has amply demonstrated the fact that gloves are superfluous. However, gloves are illustrated. The scrubbed nurse passes the first assistant an open towel, figure 167, 2, which is cuffed under the edge of the blankets, figure 167, 3, to protect the hands from accidental contamination. A second one is cuffed beneath the edge of the gown, figure 167, 4. The nurse then drops a knotted sponge moistened with 1 000 aqueous Zephiran into each of the assistant's cupped hands, figure 167, 5, 6, and he disinfects the skin by scrubbing it vigorously. The scrub is performed by rubbing the skin with short brisk strokes, transverse to the contam-

plated line of incision, figure 168, 7, 8. After the skin immediately about the line of incision has been scrubbed, the remainder of the field is disinfected by concentric strokes about the previously cleansed area, the periphery of the field being scrubbed last. Finally, creases or parts such as the umbilicus, figure 168, 9, are cleansed and the sponges are discarded into a kick pail. The nurse supplies sponges moistened with 70% alcohol and the scrub is repeated. Six changes of sponges alternately saturated with alcohol and Zephiran are used. The contrasting detergent action of the combination is advantageous. The soapy aqueous solution emulsifies the skin fats and loosens the desquamating epithelium, the dry alcohol rolls the loosened detritus off the skin. If the six changes of sponges do not produce a field which no longer yields whorls of detritus, additional scrubbing must be done. An adequate preoperative scrub and shave should make the use of more than six changes of sponges unnecessary. Following mechanical cleansing, the skin should show a rosy blush over the whole of the prepared area. The assistant now discards his gloves. If he has not worn gloves, he disinfects the skin of his hands again.

The line of incision is marked by a scratch made with the back edge of a scalpel blade, figure 168, 11, passed as indicated, figure 168, 10. The blade is discarded as soon as the scratch is made. Unless the assistant is thoroughly familiar with the surgeon's incisions, the skin scratch should be made by the surgeon before the drapes mask the anatomy.

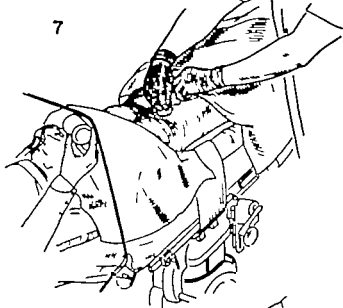
The scrubbed nurse then picks up a towel folded lengthwise so that a third of the towel is cuffed back. She grasps the towel at the extreme ends of the fold and holds it tautly in front of her, figure 168, 12, throwing the cuff of the first towel away from her. The assistant takes the towel and drapes it

DISINFECTING SKIN

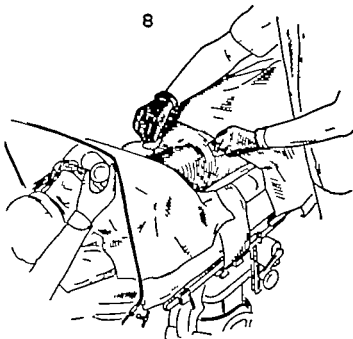


DISINFECTING SKIN

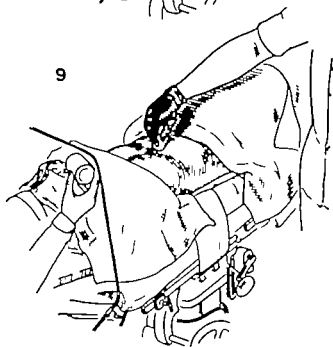
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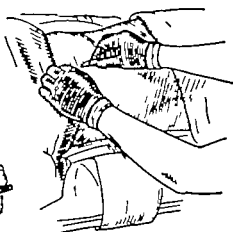
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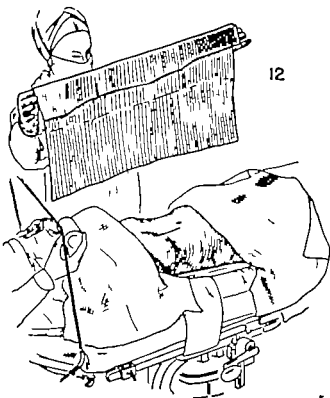
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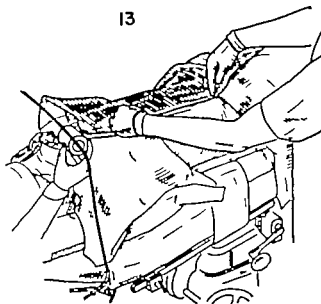
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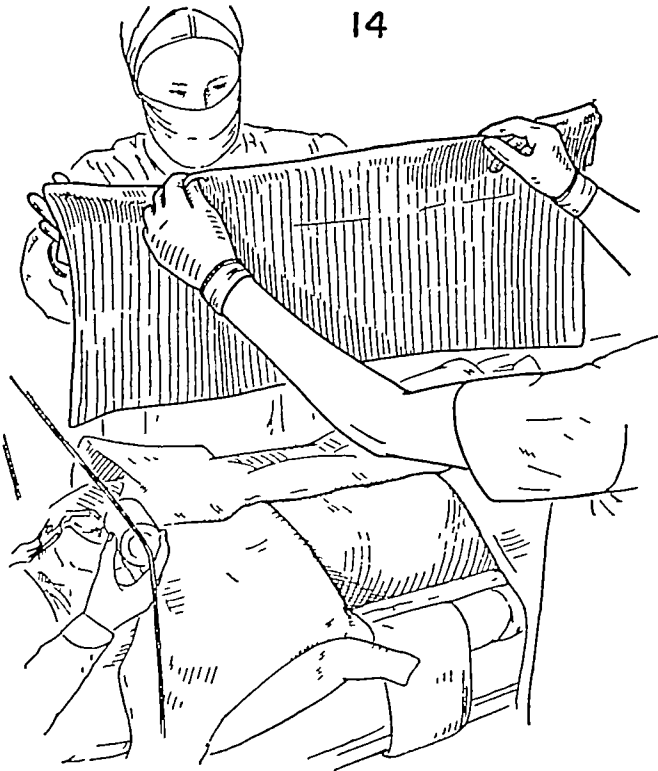


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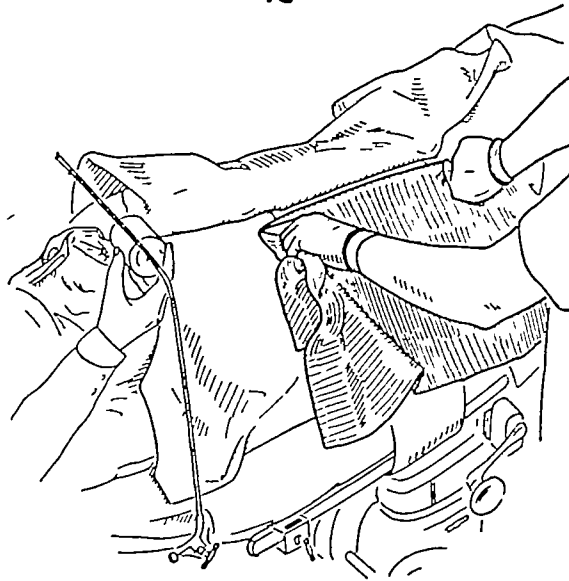


EXCLUDING SKIN

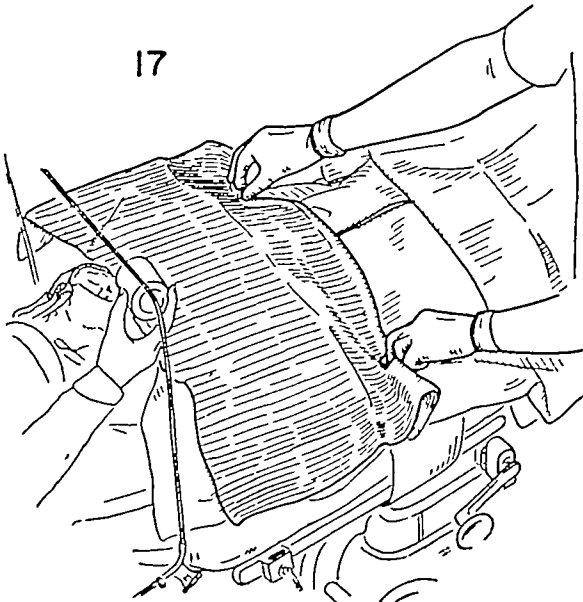
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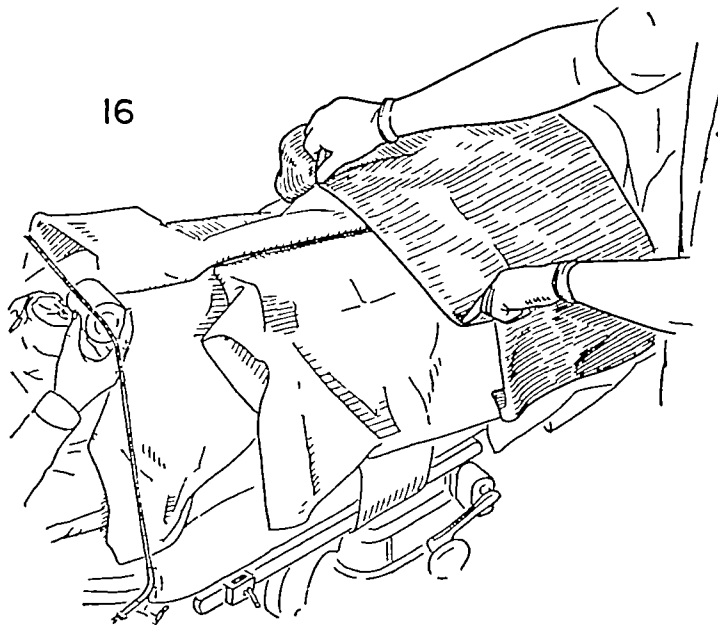
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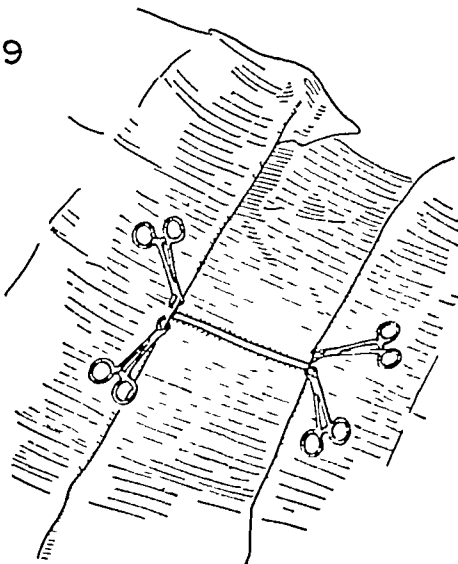
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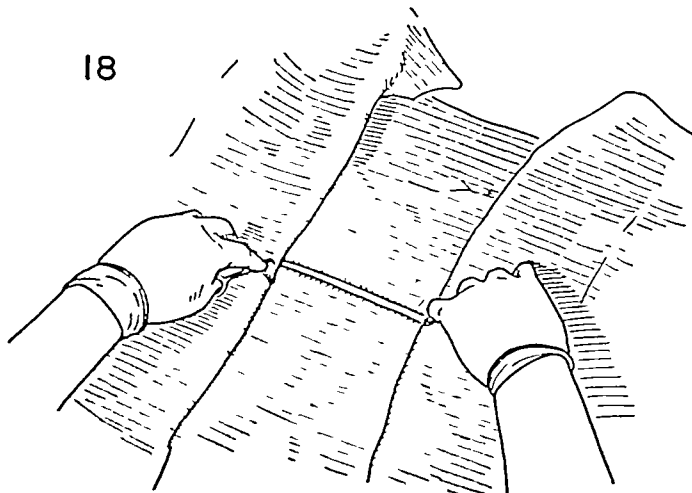
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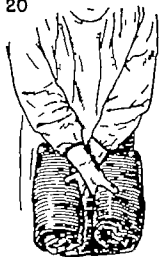


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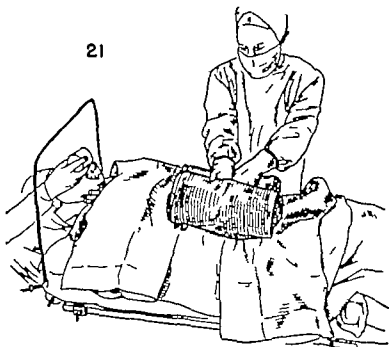


APPLYING LAPAROTOMY SHEET

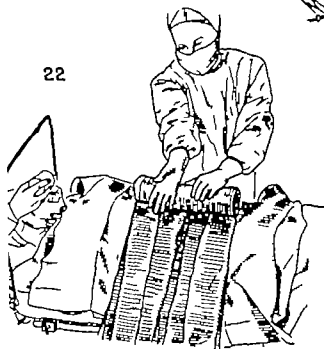
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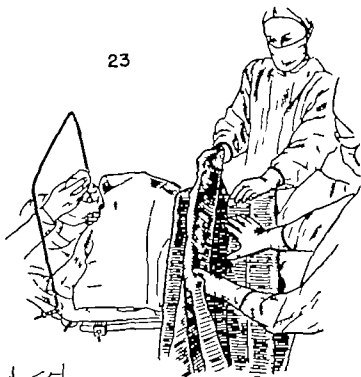
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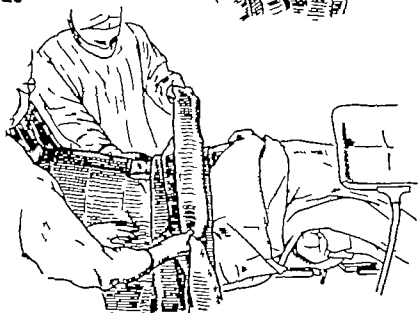
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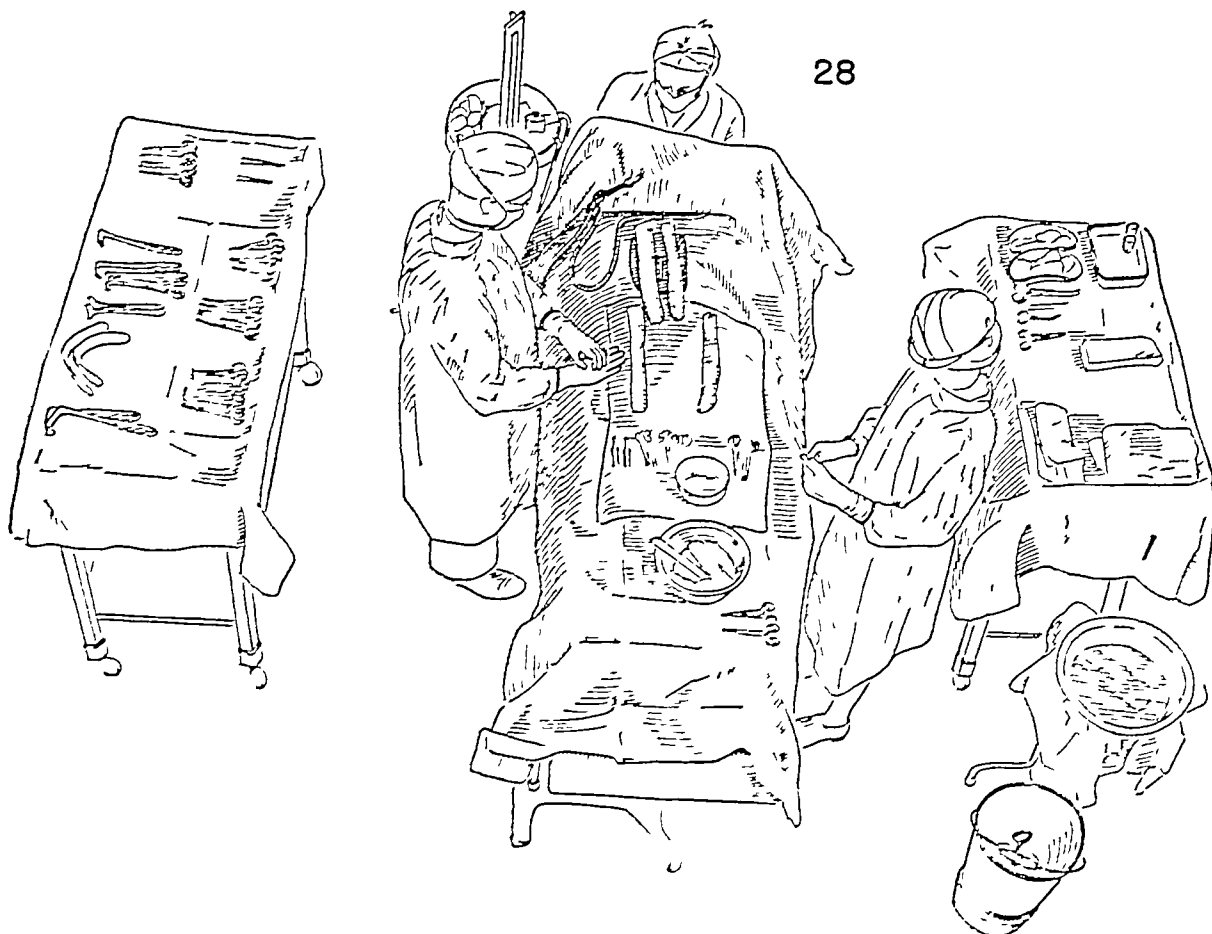
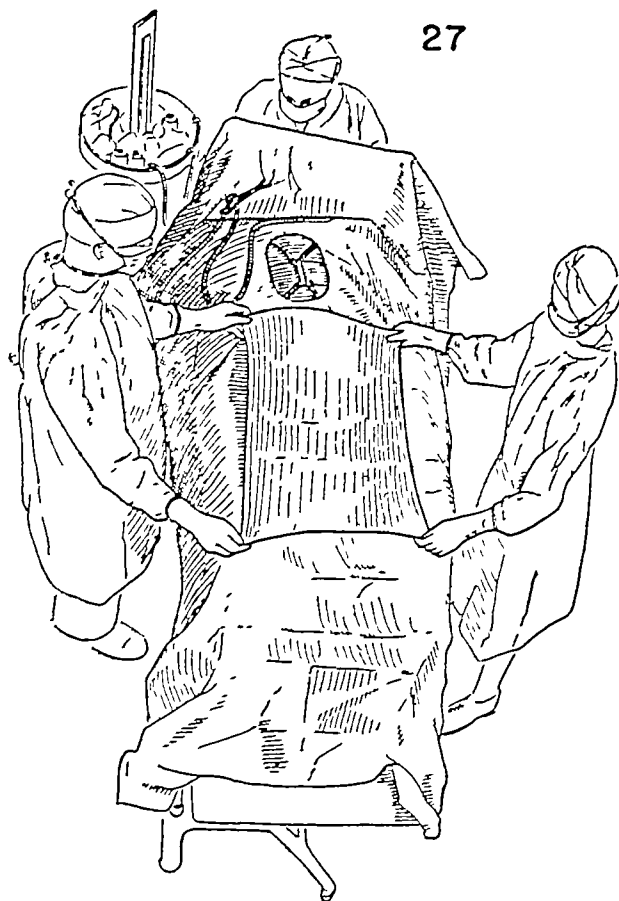
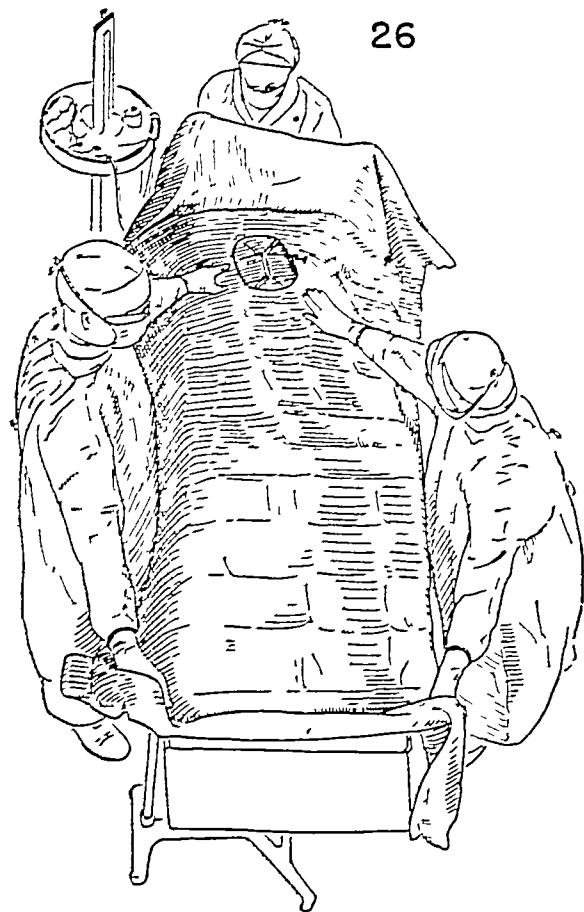
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ASEPTIC FIELD COMPLETED



carefully across the field so that the edge parallels the scratch and is about one centimeter away from it, figure 168, 13 The towel is stretched between the hands and brought straight down on the line of incision so that the undersurface of the towel contacts only disinfected skin If by chance the undersurface first contacts unsterile skin or bedding and is then dragged toward the line of incision, the operative field is contaminated The nurse then passes a second towel, this one with the cuff toward her, figure 169, 14, and the assistant drapes this towel parallel to the first, leaving approximately two centimeters of skin showing between the towels, figure 169, 15 A third towel, also duffed toward the nurse, is passed and placed across the lower end of the field, figure 169, 16 A fourth, passed with the cuff away from the nurse, is placed across the top of the field, figure 169, 17 The nurse then passes open towel clips into either hand of the assistant and he clips obliquely opposite corners, figure 169, 18, of the towels to the patient's skin When this is done, a second pair of towel clips is passed for the opposite corners, figure 169, 19 Where the operative site is anatomically irregular, the towels are moistened in 1:1000 aqueous Zephiran to facilitate draping They can often be stitched to the skin, figure 177, 11, where towel clips are inconvenient.

While the skin is being disinfected, the nurse supplies individual members of the surgical team with their gloves This is most easily done by holding the glove envelope over the basin and shaking the gloves into it She also passes each member of the team his gown so that no one need grab things from her table with the likelihood of disarranging the remaining supplies

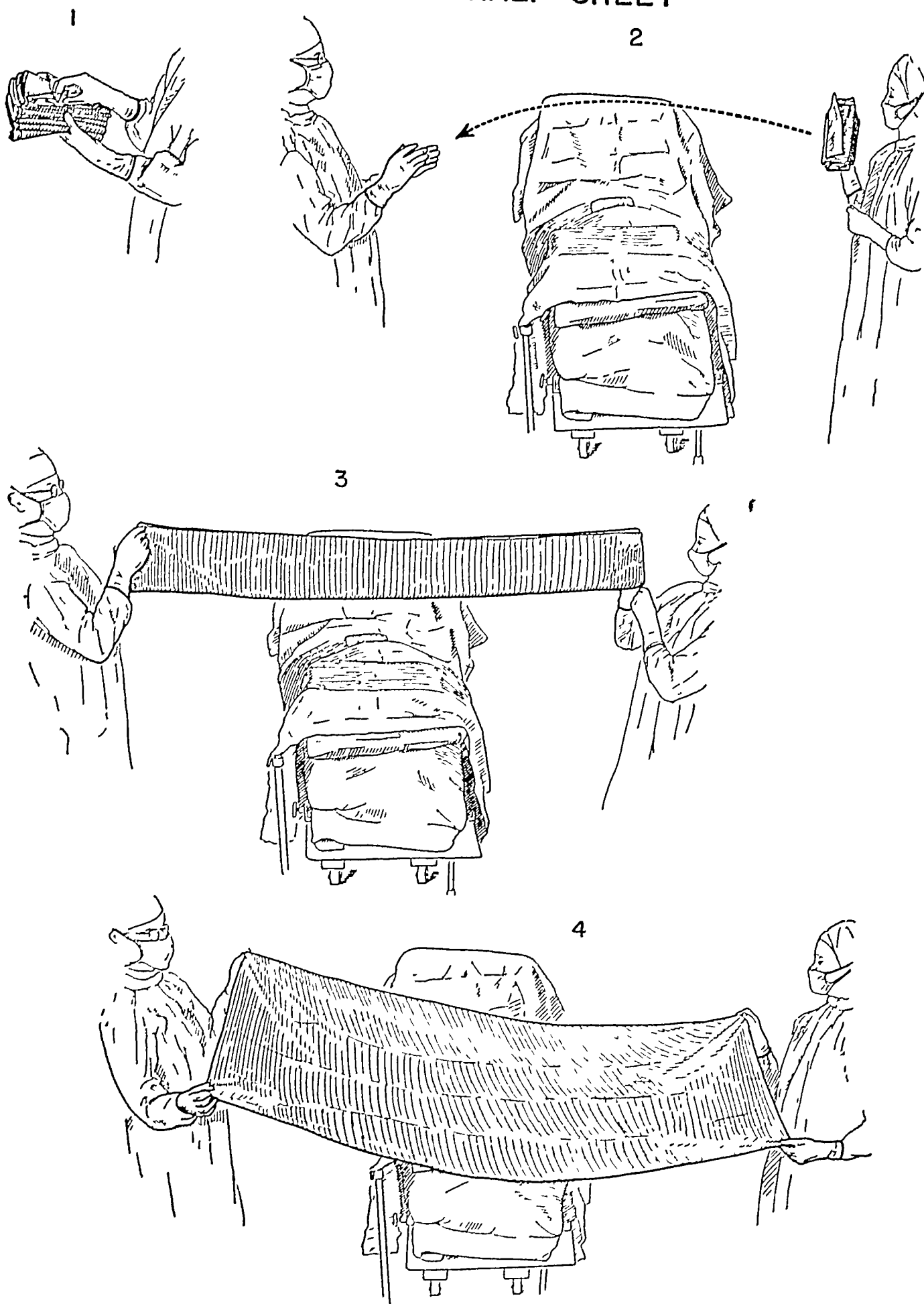
The scrubbed nurse picks up the laparotomy sheet with her arms crossed as shown in figure 170, 20, and places the hole in the

sheet directly over the operative site, figure 170, 21, and flips the rolled ends to either side, figure 170, 22 The instrument man and nurse then place one hand on the drape to keep the hole in the proper position and slip the fingers of the opposite hand beneath the top pleat of the drape, figure 170, 23, using this pleat to protect their gloves as they open the fanfolded sheet to cover the anesthetist's barrier, whether it be a Mayo stand or a wire hoop, figure 170, 24 A similar procedure is repeated with the other end of the drape, figure 170, 25, to cover the Mayo stands which have been located and fixed at the proper height so that the instrument man and nurse command a view of the operative field as well as have their source of supplies convenient, figure 171, 26 The scrubbed nurse passes the suction tubing to the first assistant who clips it in place. The nurse opens the moistened towel by grasping the presenting corners and pulling one edge taut. The instrument man takes the lower edge and the towel is draped below the operative field to prevent instruments from slipping to the floor, figure 171, 27 The instrument man then arranges his instruments on the flat surface of the Mayo stand and the nurse brings the smaller basin, previously loaded with instruments, to the field. The circulating nurse fills the remaining basin with Cushing's Solution,² figure 156 Sponges are arranged on the operative field ready for the surgeon

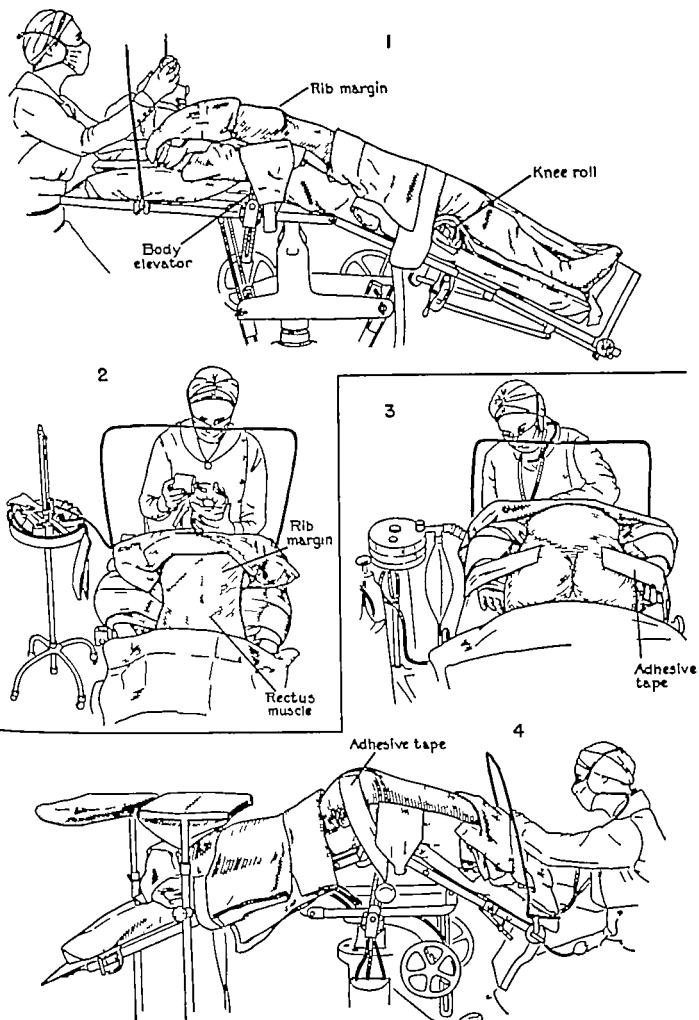
If the laparotomy sheet does not cover the Mayo stands properly, a half sheet can be opened and draped across the exposed stands. The half sheet is unfurled by the nurse who grasps the presenting corners, figure 172, 1, and tosses the sheet across the field to the instrument man, figure 172, 2,

² Cushing H Concerning the Poisonous Effect of Pure Sodium Chloride Solution upon the Nerve Muscle Preparations. *Am. J. Phys.* 6:177 1901

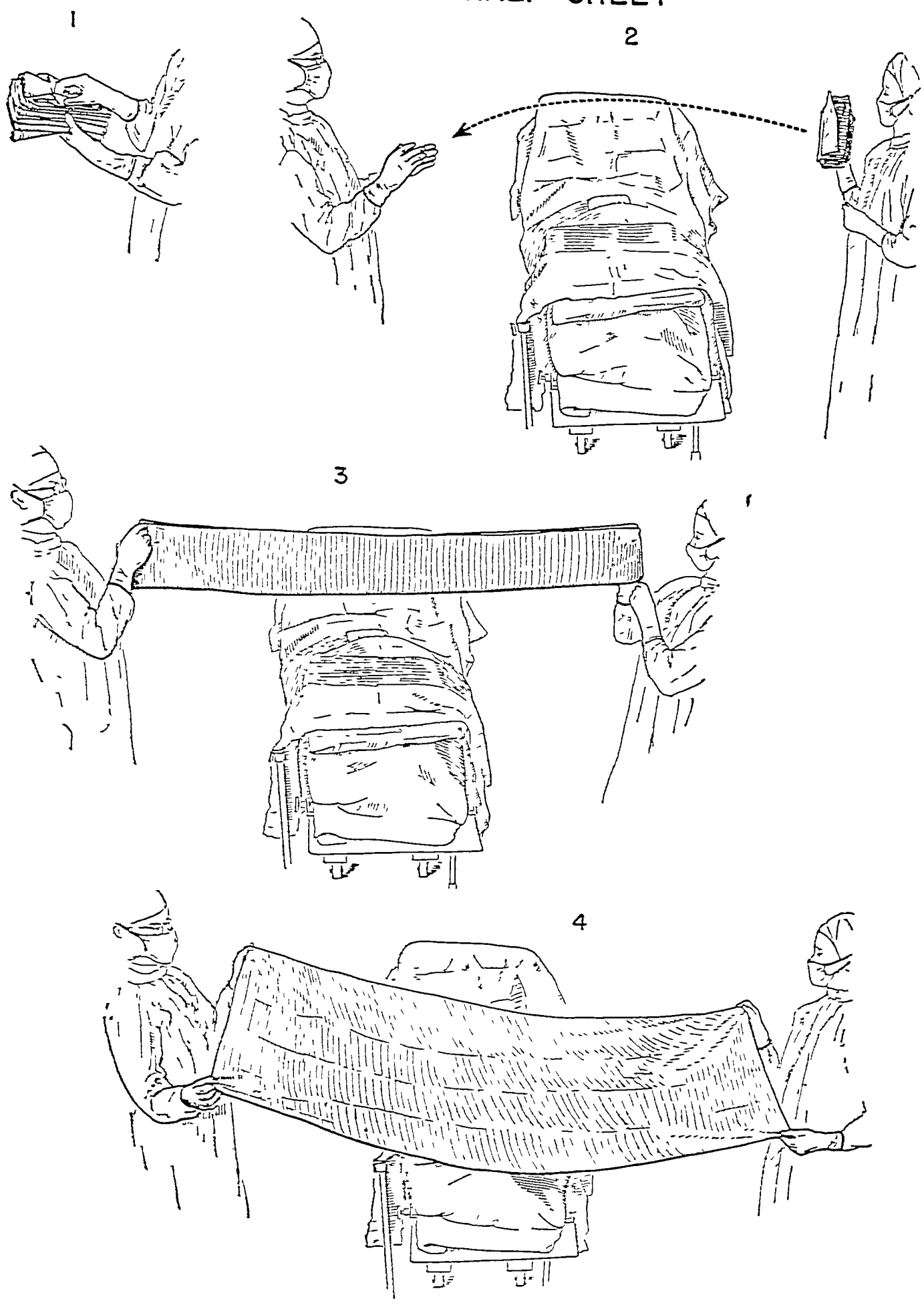
APPLYING HALF SHEET



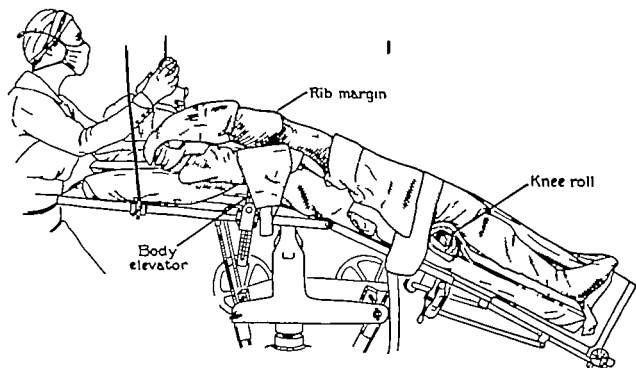
POSITIONING PATIENT



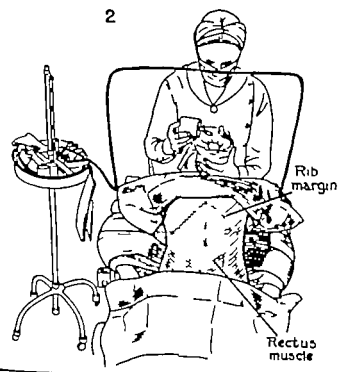
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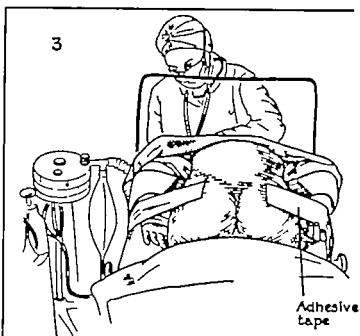
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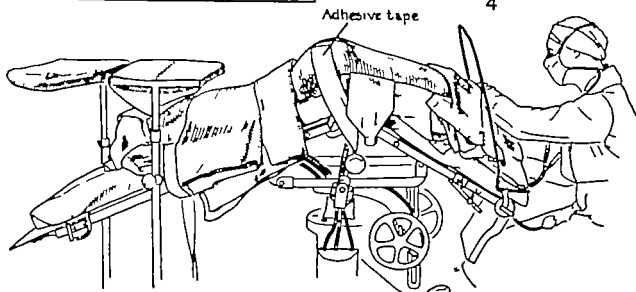
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POSITIONING PATIENT

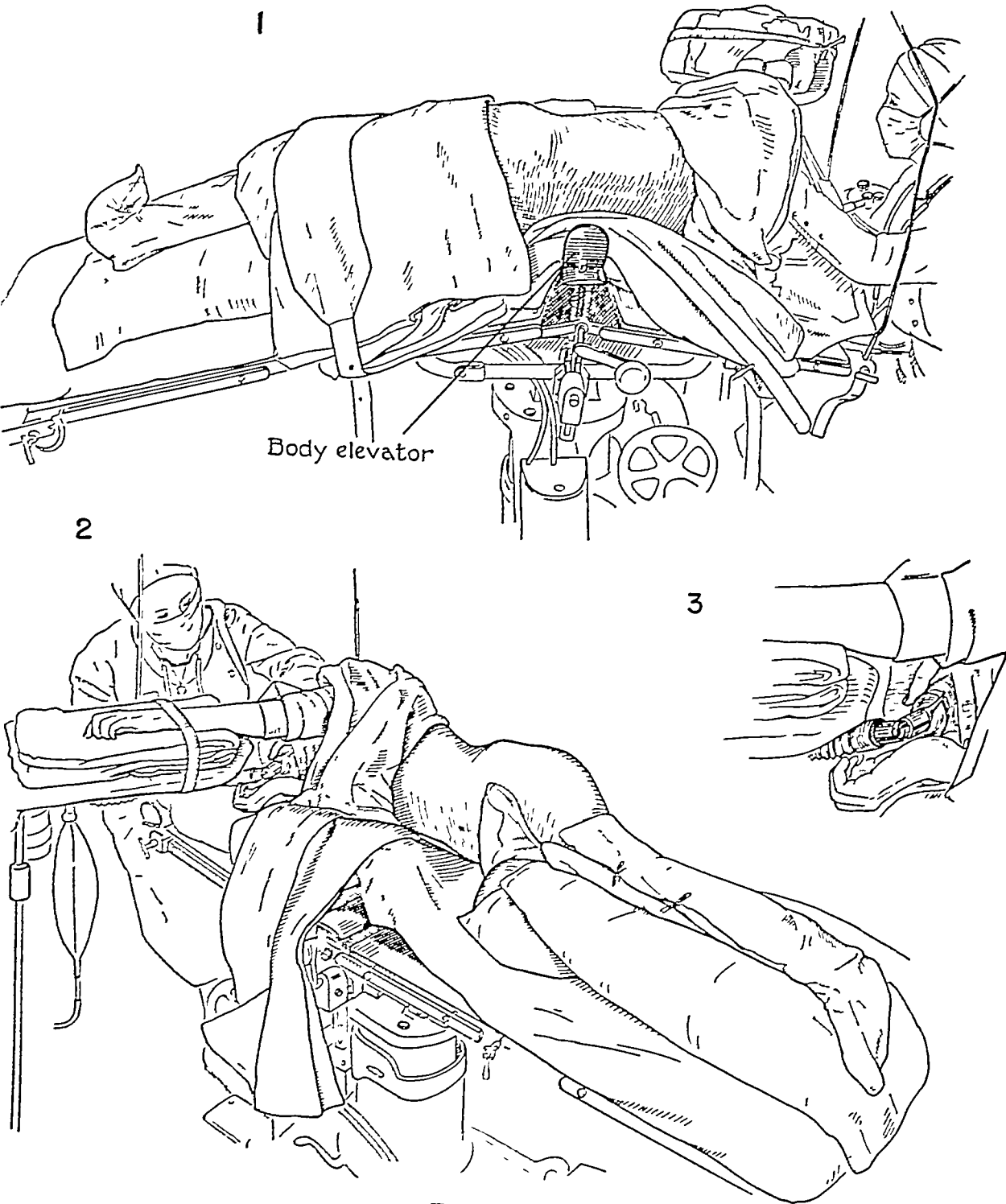


FIGURE 174

POSITIONING PATIENT

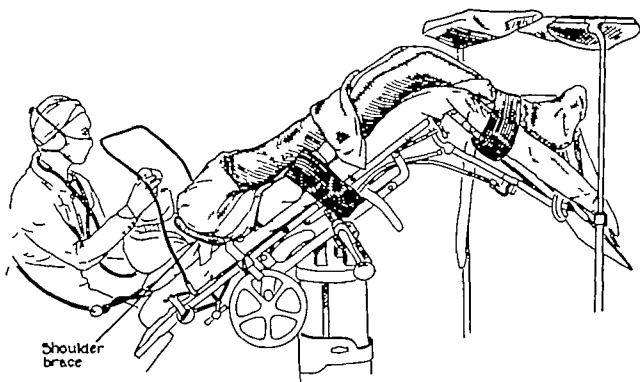


FIGURE 175

who catches the end and finds the corners as the nurse opens the longitudinal folds, figure 172, 3 The sheet is held tautly as it is lowered to the table, figure 172, 4

The position for cholecystectomy depends upon hyperextension of the trunk at the costal margin and a semisupine position to thrust the undersurface of the liver into the wound, figure 173, 1, 2 Location of the gall bladder rest under the spinous process of the tenth thoracic vertebra, the use of a ten centimeter roll to flex the thighs, and dependence on the foot board to prevent the patient from slipping off the table are noteworthy points.

Excision of a pilonidal sinus or a hemorrhoidectomy can be done readily in the position illustrated in figure 173, 4 The patient is placed prone on the operating table with the iliac crest at the level of the break in the table. After the arms and legs have been restrained, the table is broken enough to present the operative site The buttocks are cleansed with ether and straps

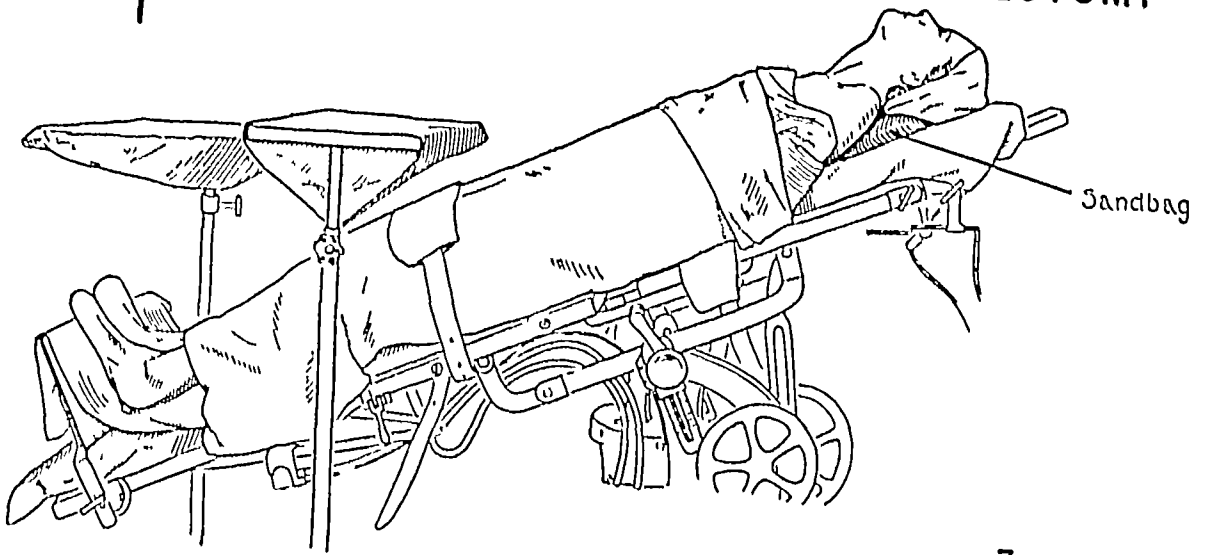
of ten centimeter adhesive are applied to spread the gluteal cleft widely, figure 173, 3

Incisions into the lumbar fossa give best exposure when the patient is positioned on the opposite side with no support for the abdomen. Sufficient lateral flexion of the trunk can be obtained with an elevator at the level of the ninth and tenth thoracic spines to cause the wound to gape, figure 174, 1 The intra peritoneal viscera fall away with the relaxed abdominal wall. The trunk is maintained in this position easily if the lower thigh is flexed, figure 174, 2, and the uppermost arm is supported on a stand The latter arrangement provides access for the anesthetist, figure 174, 3

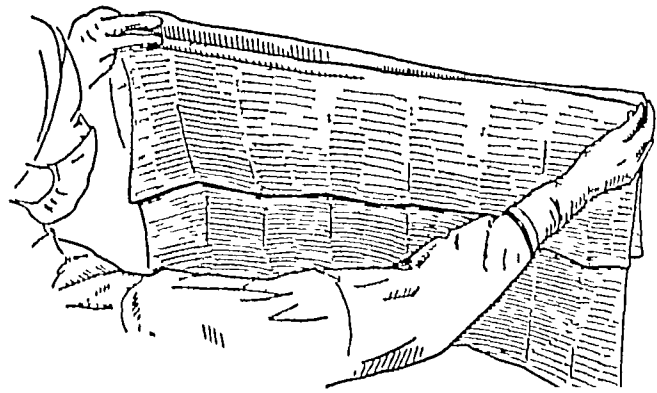
Exposure of the pelvic cavity may be obtained by suspending the recumbent patient at a 45° angle, figure 175 The patient is prevented from sliding off the table jointly by flexing the knees over a break in the table and by padded shoulder braces, adjusted to distribute the patient's weight equally Brachial plexus palsy or

POSITIONING PATIENT FOR THYROIDECTOMY

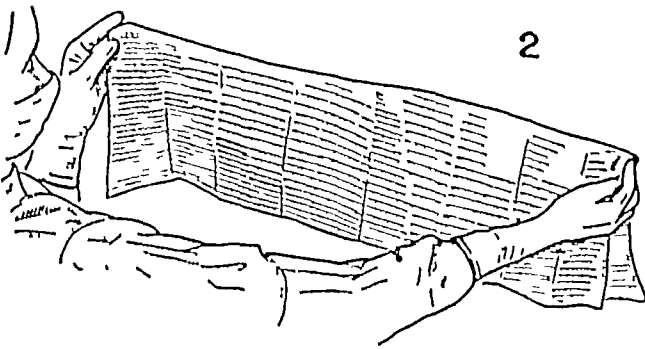
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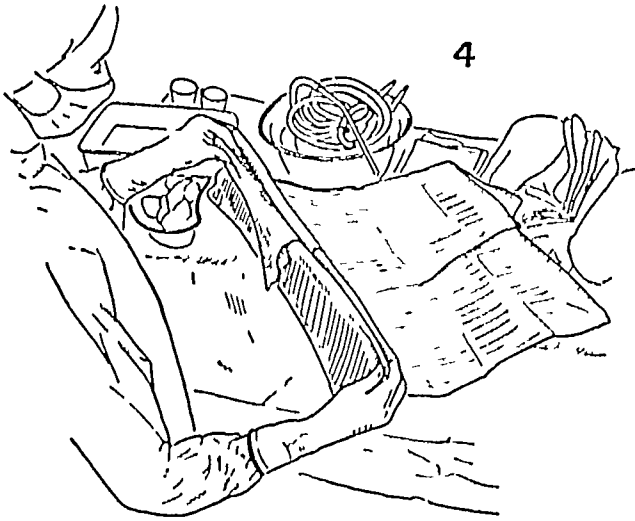
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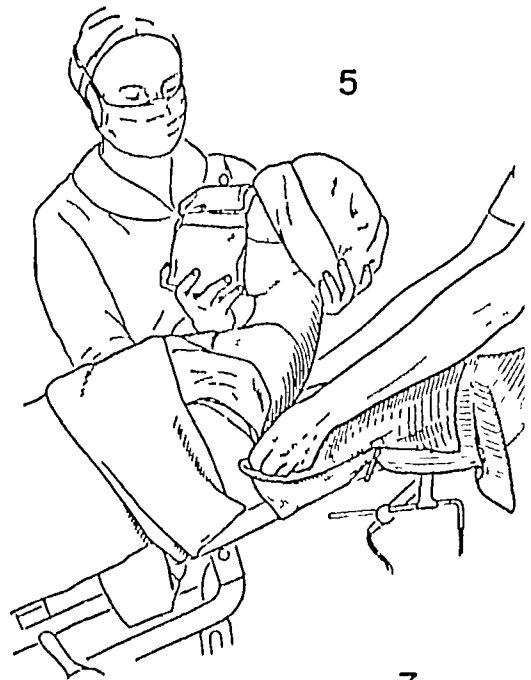
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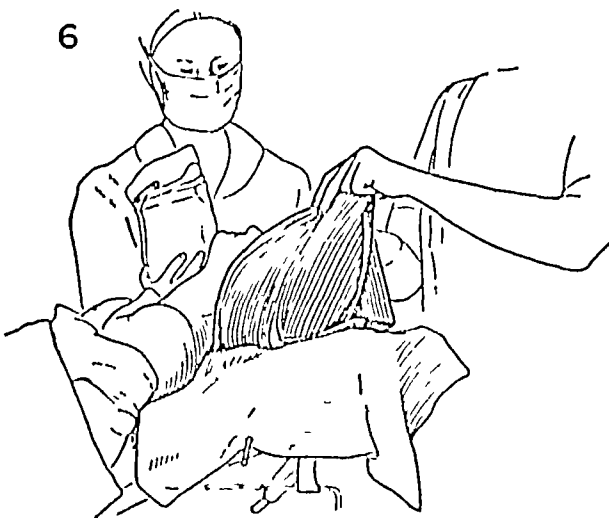
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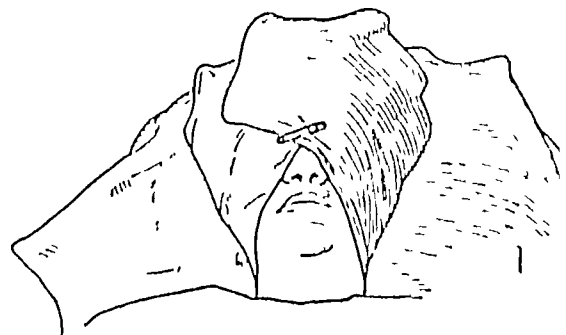
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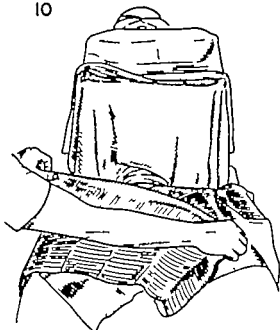


DRAPING FOR THYROIDECTOMY

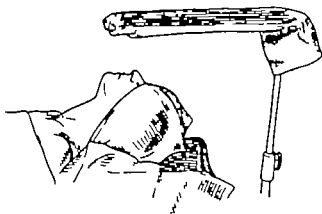
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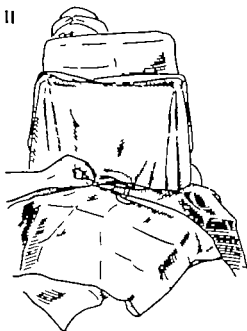
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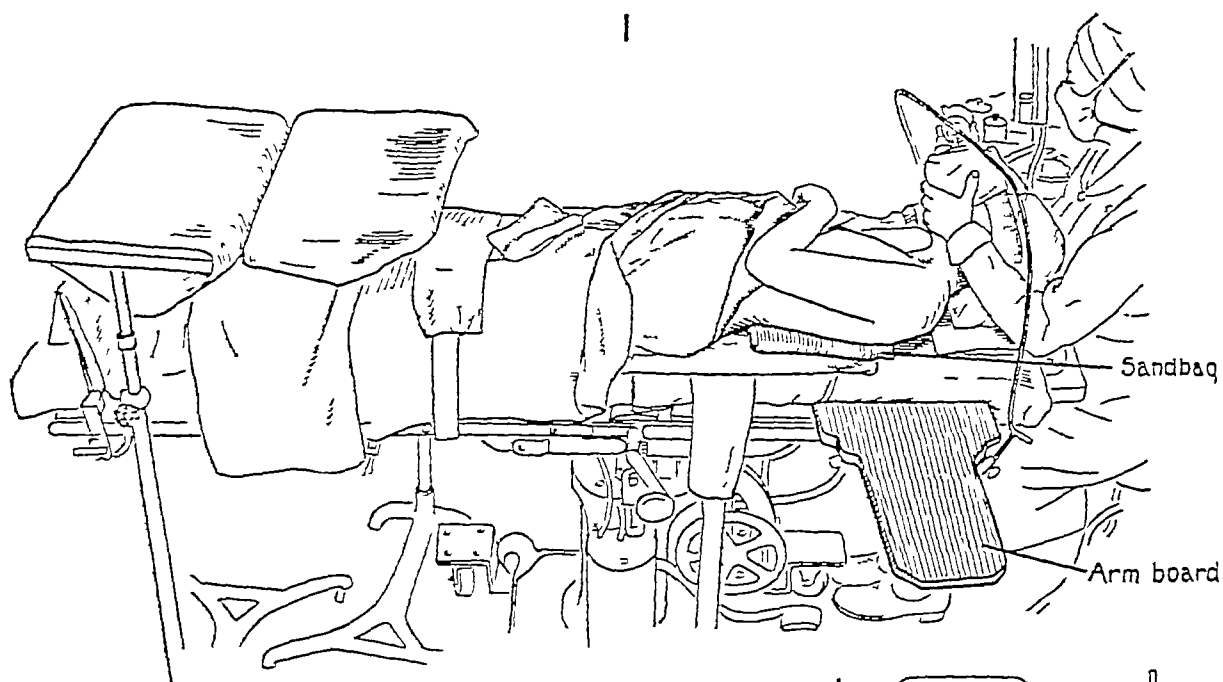


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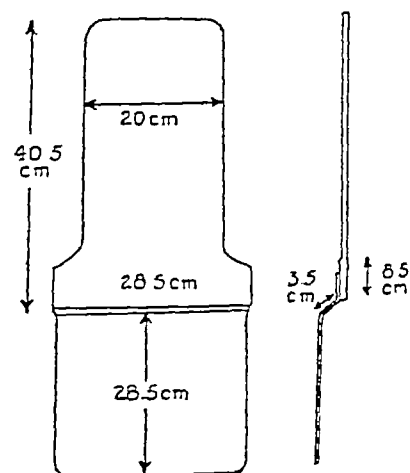
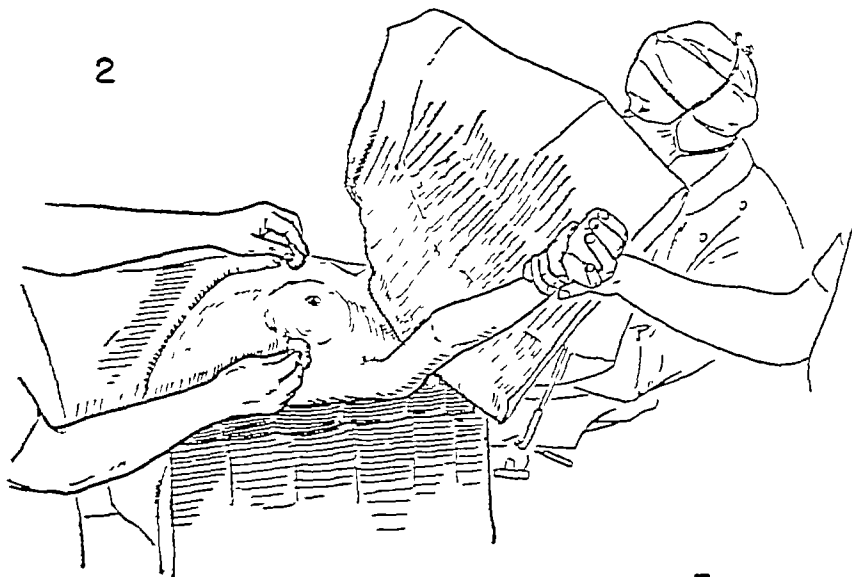


POSITIONING PATIENT FOR MASTECTOMY

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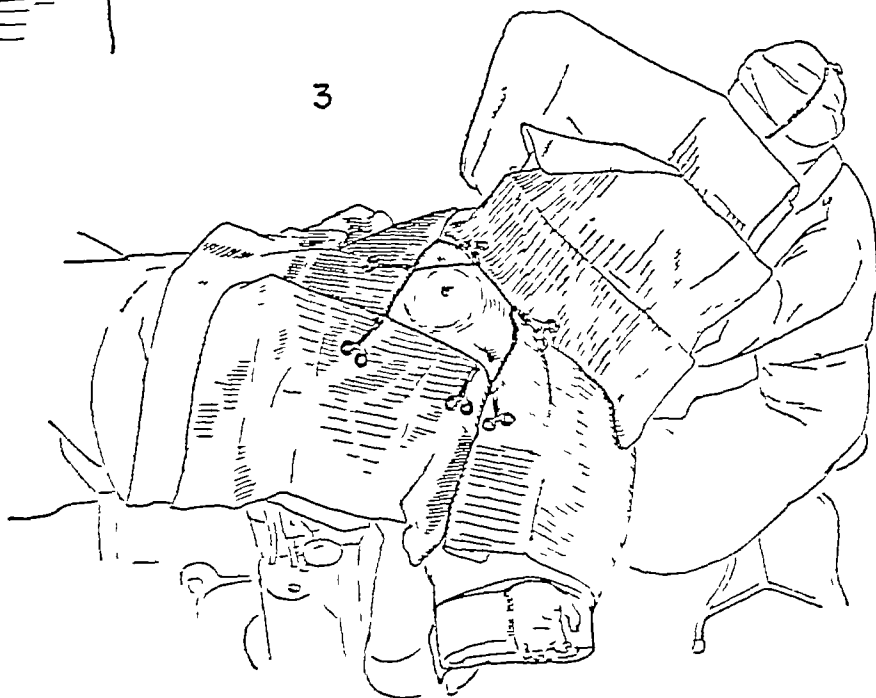


2



Plan of arm board

3



DRAPING FOR MASTECTOMY

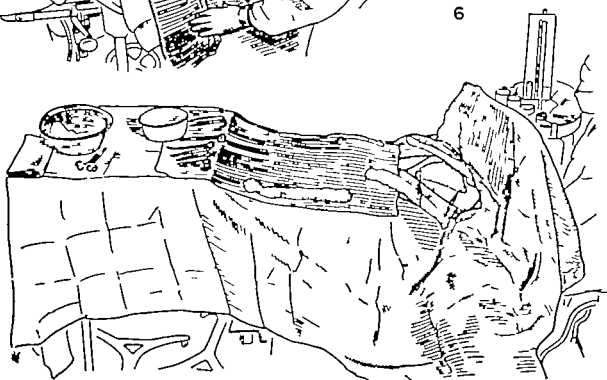
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thrombophlebitis are the penalties for prolonged suspension with maldistribution of pressure.

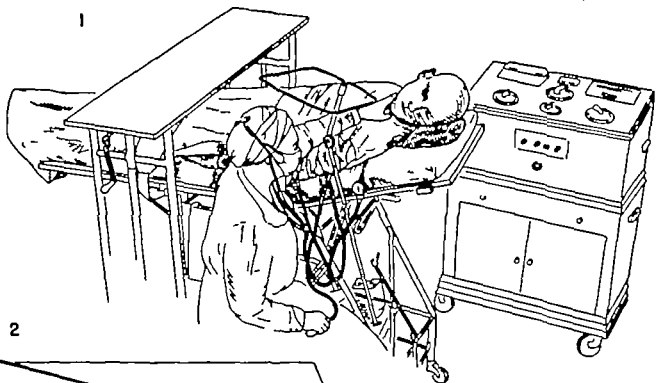
Operations upon the anterior and lateral aspects of the neck are conveniently done in the position illustrated for thyroidectomy, figure 176, 1. The supine patient is tilted to an angle of 20 to 25 degrees and a loosely filled sandbag is placed beneath the shoulders to thrust the seventh and eighth spinous processes forward so that the neck is extended sufficiently to bring the lower edge of the mandible in a vertical plane. Details of draping differ from that described previously because of the complexity of the anatomic site. A towel is folded in half longitudinally, figure 176, 2, and the folded edge is approximated to the long edge of an open towel, figure 176, 3. The pair of towels is then fanfolded transversely for easy handling, figure 176, 4. These towels are moistened with 1:1000 aqueous Zephiran and wrung out. The scrubbed nurse passes the towels with the folded one toward the assistant, its folded edge uppermost. The anesthetist lifts the patient's head while the assistant slips the towels beneath the shoulders, figure 176, 6. The head is then lowered onto the moistened towels and the anesthetist gathers any protruding wisps of hair upward. The assistant wipes the side of the neck and face upward with the edge of the folded towel, figure 176, 6, to capture all the hair. The ends of this towel are pulled tightly across the cheeks and pinned where they cross the bridge of the nose, figure 176, 7. The open towel is left to cover the upper end of the mattress. The skin is disinfected as already described and the line of incision is marked by pressing a taut silk thread against the skin, figure 177, 8. A small stand is placed so that it covers the patient's face with its edge above the chin, figure 177, 9. This stand must be high enough to permit the anesthetist to work

Double moist towels are draped lengthwise from the line of incision over the Mayo stand. Moist towels, folded longitudinally, are placed to demarcate the field below the contemplated incision, figure 177, 10. Towel clips are applied to fasten the towels well back on the sides of the neck. The towels are stitched to the skin in front, where clips would be in the way, figure 177, 11, 12. The completed set-up for a thyroidectomy is shown in figure 177, 13.

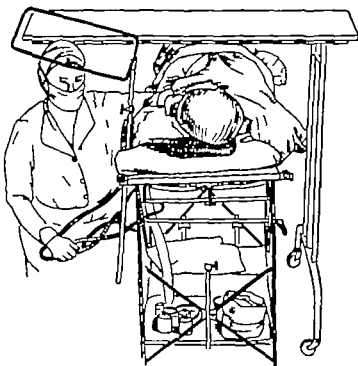
A movable arm board and a flat sandbag placed beneath the lower scapula are the important factors in proper positioning of the patient for mastectomy, figure 178, 1. The skin of the breast and axilla are disinfected atraumatically by means of a moist preoperative dressing, Chapter XII. That of the neck, thorax, and arm is scrubbed thoroughly so that the skin from the lower neck to the umbilicus and from the opposite midclavicular line to the table level, as well as that above the elbow, is disinfected, figure 178, 2. Moistened towels are clipped in position to demarcate the field, figure 178, 3, and the mastectomy sheet is applied, figure 179, 4, 5. When a biopsy is done before the mastectomy, it is wise to discard all instruments and drapes used during the biopsy to avoid the direct implantation of carcinoma cells into the operative wound. The most convenient way is to make up a separate mastectomy kit and nurse's kit to provide the dry goods and instruments for the biopsy. A moistened gauze pad is sutured to the breast to exclude the biopsy wound and most of the skin from the operative field, figure 179, 6. The movable arm board permits the surgeon to adjust the degree of adduction to that offering the most ideal exposure of the axilla and the maximum relaxation during closure of the skin. The generous mastectomy sheet provides ample protection without moving the drapes.

POSITIONING PATIENT FOR CRANIOTOMY

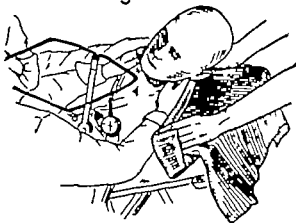
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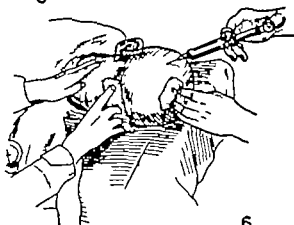
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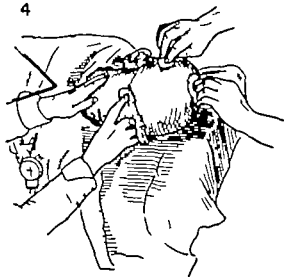
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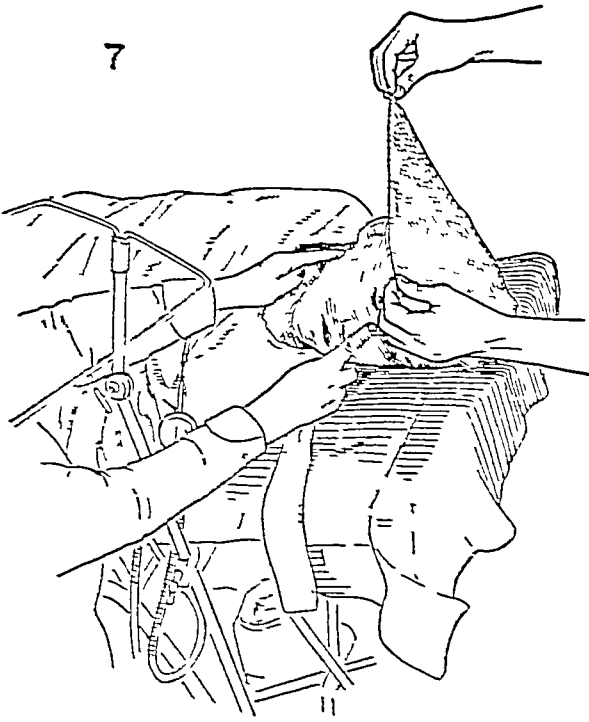


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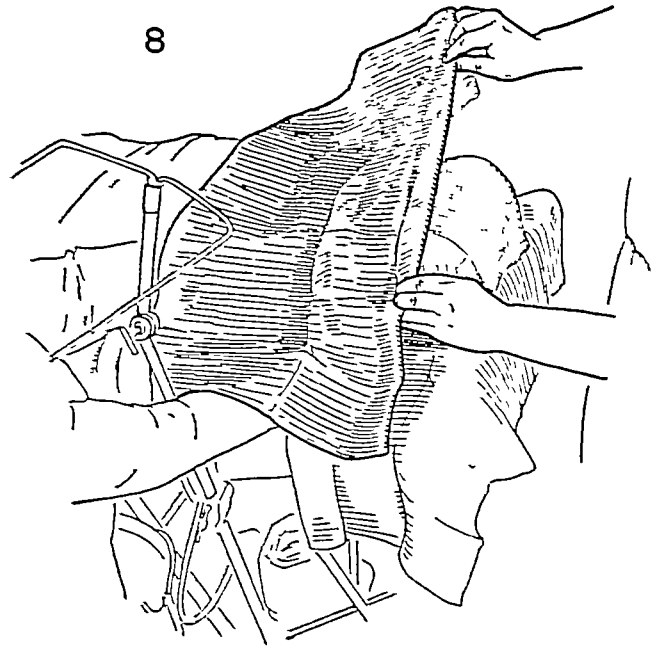


DRAPING FOR CRANIOTOMY

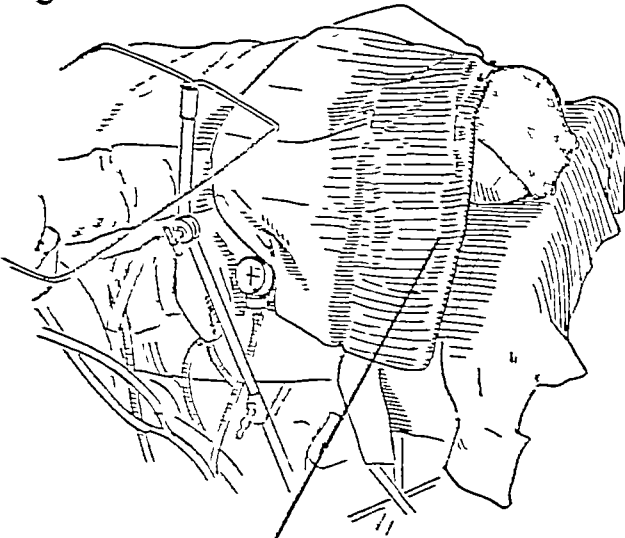
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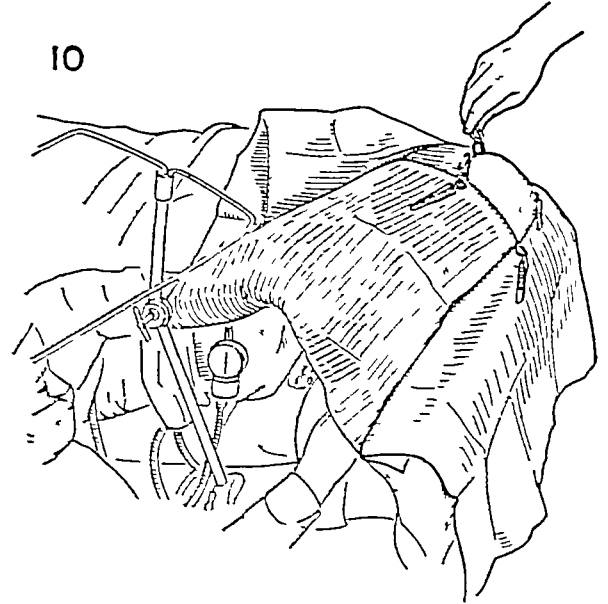
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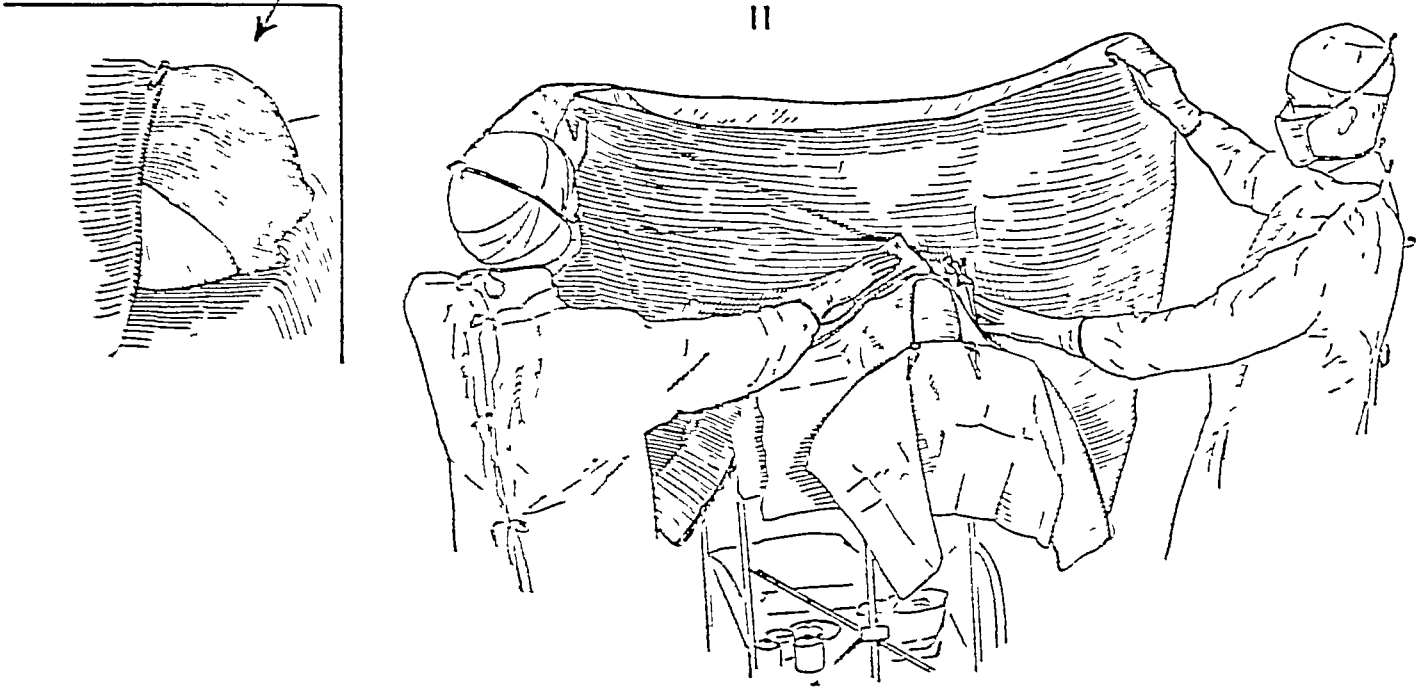
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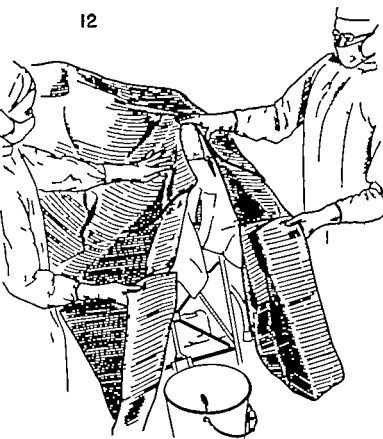


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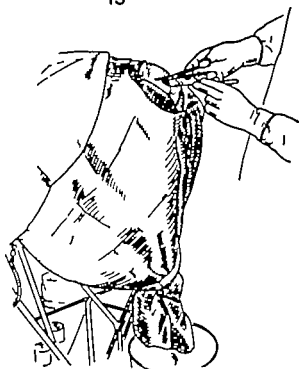


DRAPING FOR CRANIOTOMY

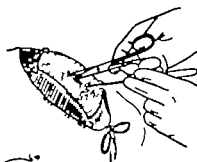
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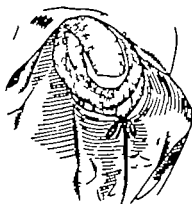
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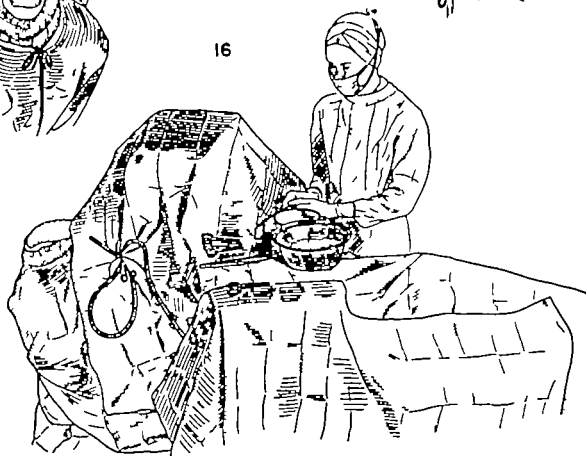
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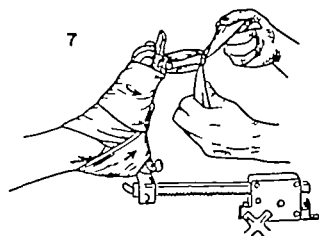
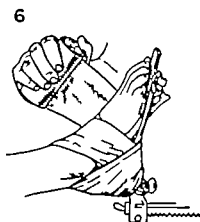
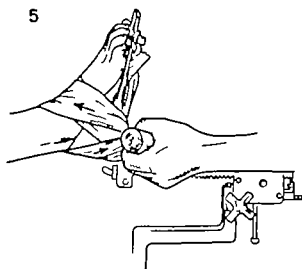
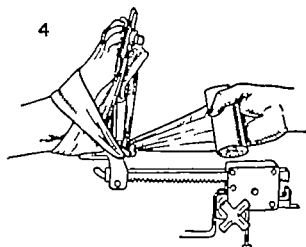
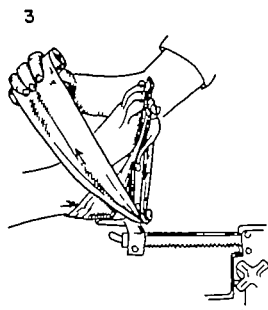
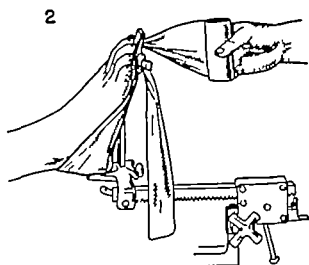
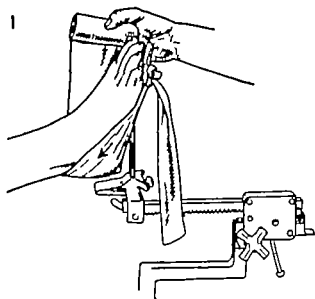


The earmark of a successful neurological surgeon is the precision and care with which the patient is positioned and the drapes applied. Figure 180 illustrates the major steps in setting up for a craniotomy. The patient is restrained as illustrated previously and the head is positioned with the help of sandbags, figure 180, 1, 2. The sandbags and mattress are covered with a moistened sterile towel, figure 180, 3, and the scalp is scrubbed. Note that the anesthetist protects the eyes by holding a sponge against them to catch any germicide which might run down, figure 180, 4. The scalp can then be infiltrated with novocaine, figure 180, 5, and the incision planned and marked with a scratch, figure 180, 6. A single thickness of gauze, moistened in aqueous Zephiran, is then applied over the head and its ends are pulled together by the anesthetist. This serves to confine any loose hair which might find its way into the operative field when the patient's scalp has only been partially shaved, figure 181, 7. A moistened towel folded longitudinally is placed transversely across the temporal region to demarcate the lower limits of the operative field. This towel is fixed to the scalp just above the ear with a safety pin to prevent the auricle from protruding into the field, figure 181, 9, and also to anchor the towel so that subsequent towels can be applied without danger of slipping. The remaining towels are then placed and secured with towel clips, figure 181, 10. The craniotomy sheet is then put on, figures 181, 11, 182, 12. The skirt of the sheet is knotted together over the kick pail so that irrigating fluid and blood drip into the pail rather than onto the floor, figure 182, 13. The surgeon cuts the gauze overlying the contemplated line of incision with a scissors, figure 182, 14, 15. The instrument man's and nurse's view of the field is shown in figure 182, 16.

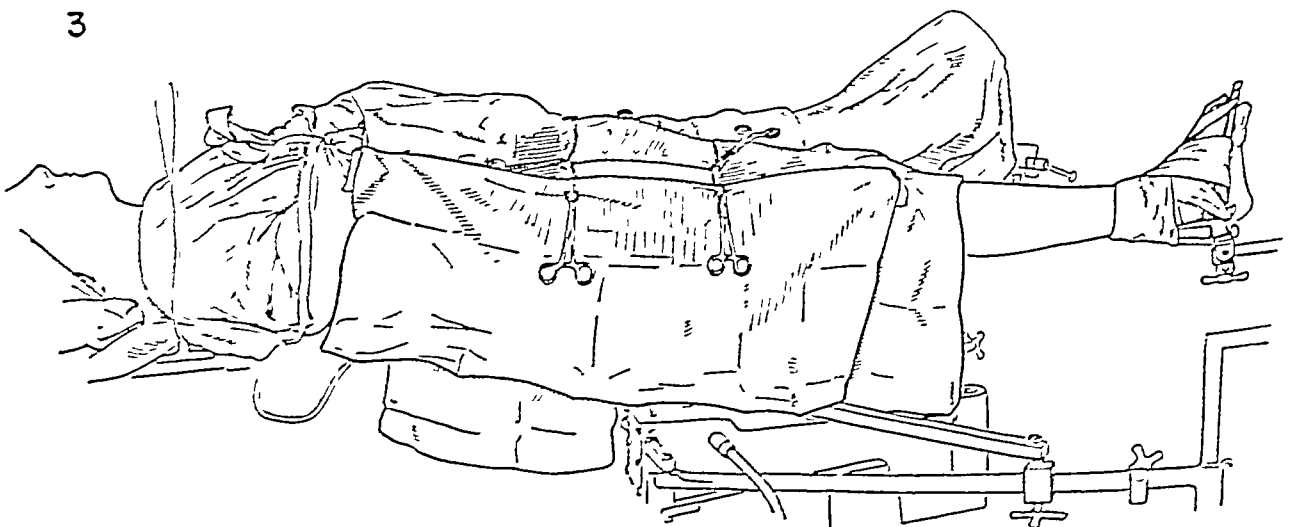
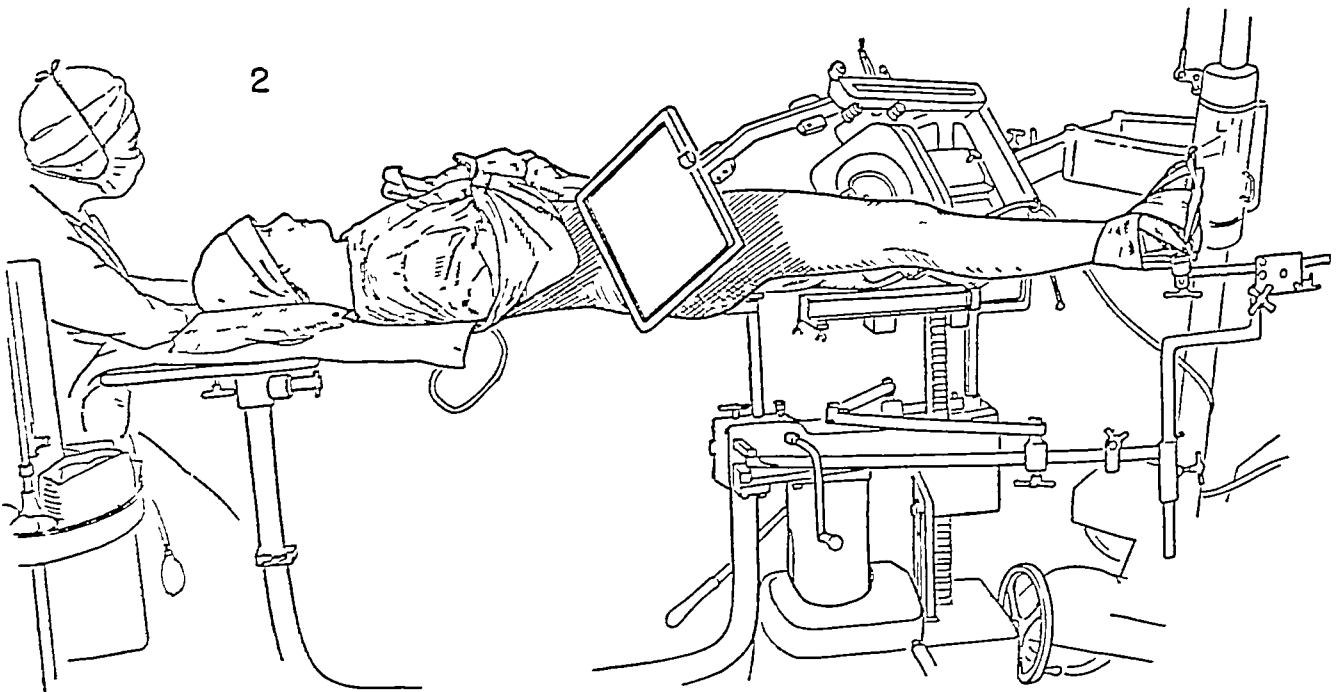
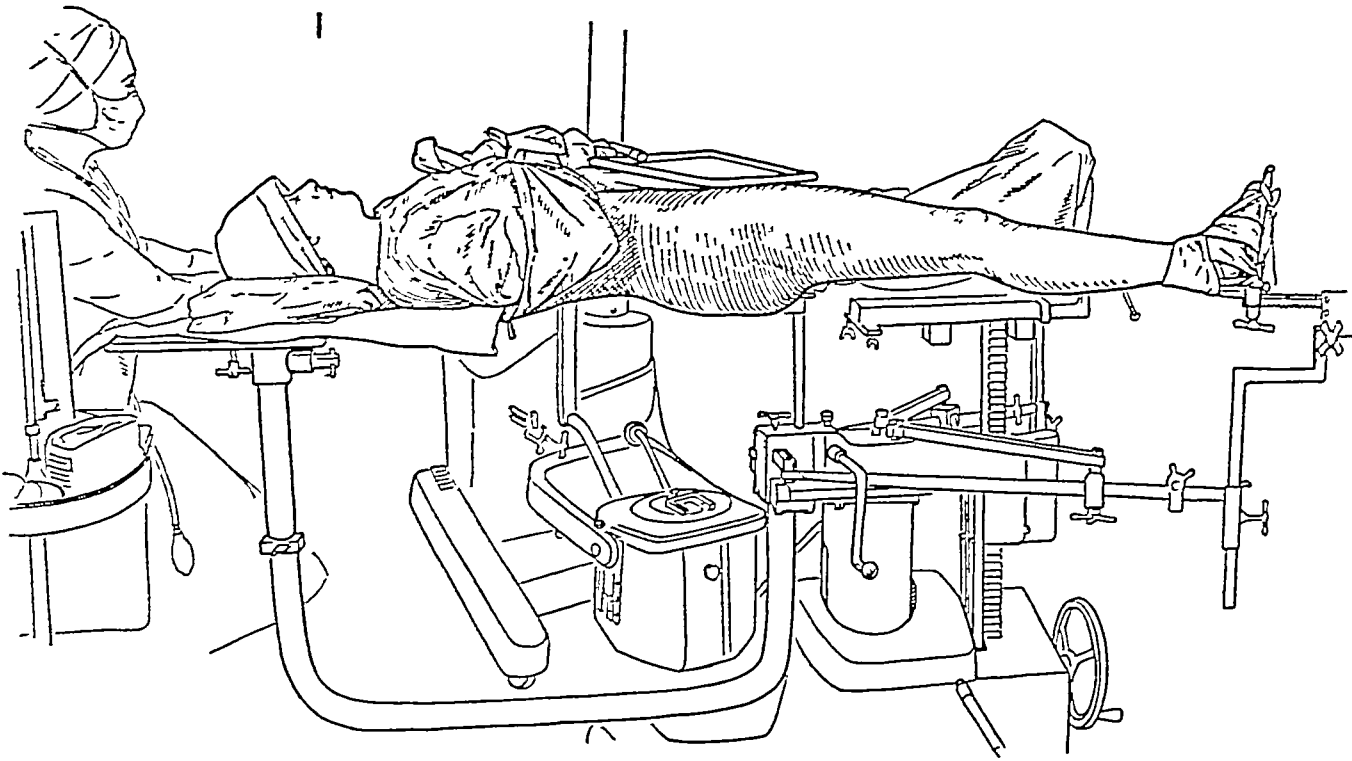
Fracture surgery is rendered easier by proper positioning of the patient and accurate control of the extremity. The use of a well designed fracture table to supplant the unsteady and tiring efforts of assistants simplifies most procedures involving fractures of the long bones. Figure 183 illustrates the fixation of the patient's foot to the foot plate of the fracture table. This often neglected detail is the most critical part of the preoperative set-up. The position for fluoroscopy of a fractured hip is shown in figure 184, 1, 2, where both antero-posterior and lateral fluoroscopic views can easily be obtained. The skin overlying the trochanter is then disinfected and moist sterile towels are clipped to the operative site, figure 184, 3. The draping is completed by putting a half sheet over each foot and a laparotomy sheet over the remainder of the field. The fluoroscope can be draped for use in the sterile field by applying the cover illustrated in figure 87. This cover is unfolded, figure 185, 4, 5, and the skirt is held out of the way, figure 185, 6, 7, while the sterile steel frame is slipped over the fluoroscopic screen. The sterile skirt is then clipped around the arm of the fluoroscope, figure 185, 8, so that the screen is protected adequately and can be used directly in the sterile field, figure 185, 9.

Compound injuries are nicely cared for by a technic shown in figure 186. The care of a compound fracture of the tibia is illustrated although the technic is equally applicable for trivial injuries to the hand, laceration of the scalp or any area where wound excision or debridement is contemplated. Figure 186, 1, illustrates the patient suspended on the fracture table with a crutch under the knee on the injured side to help position the extremity. Continuous spinal anesthesia is illustrated. The patient's arms are restrained by turning up the tail of the hospital gown and pinning it

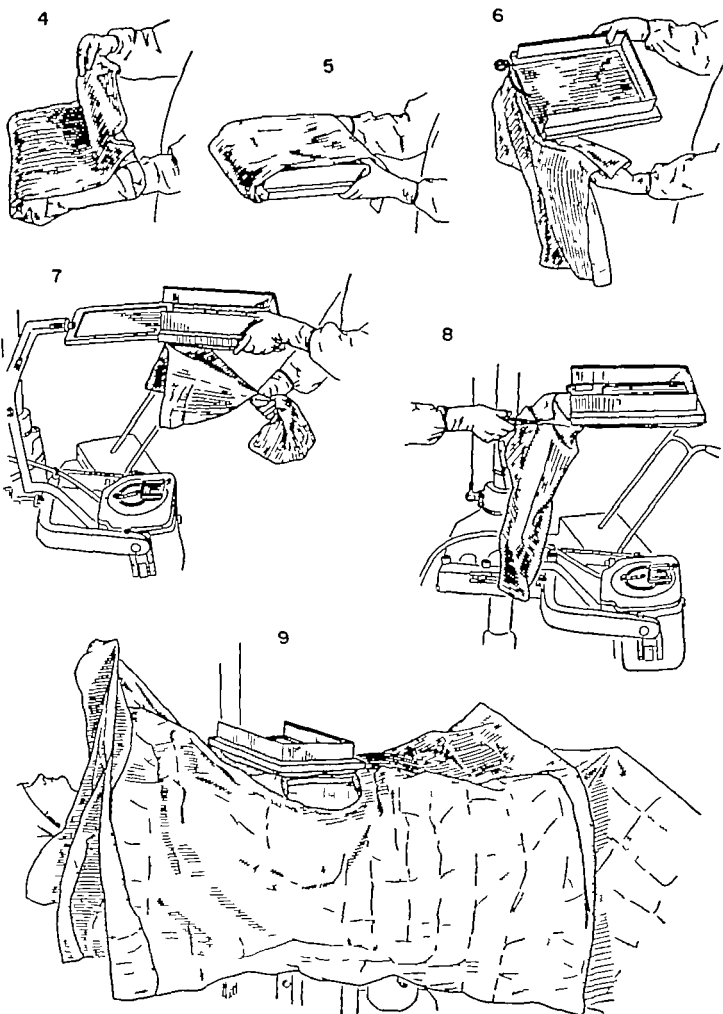
LASHING FOOT TO FRACTURE TABLE



POSITIONING PATIENT ON FRACTURE TABLE



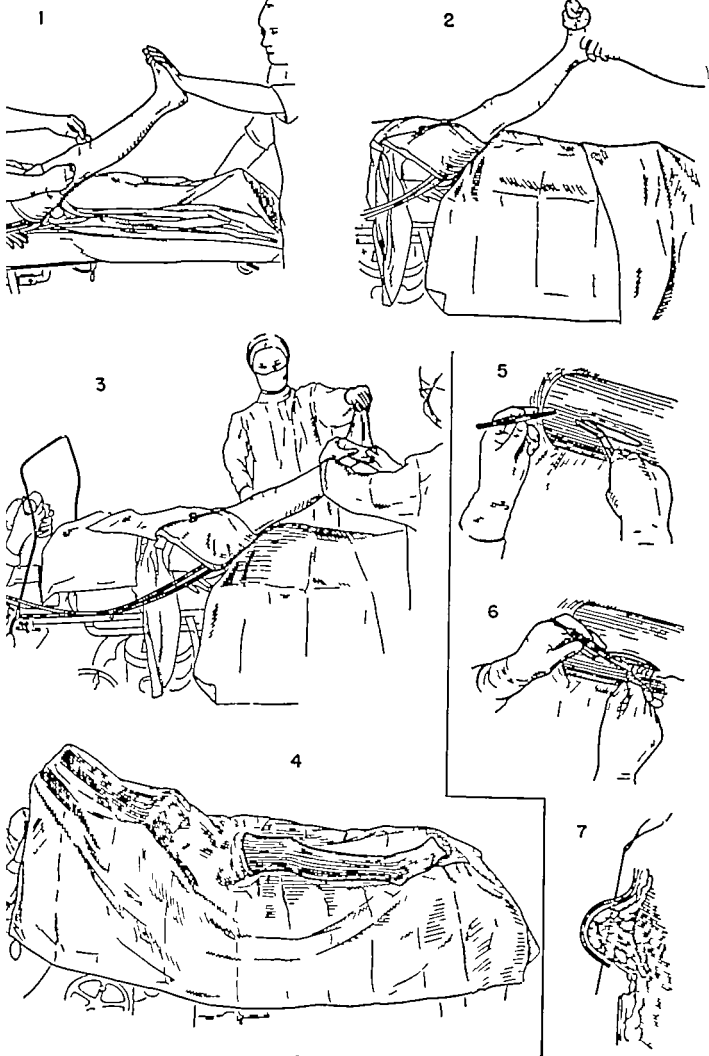
DRAPING FLUOROSCOPE



DRAPING FOR EXCISION OF WOUND



DRAPING EXTREMITY



snugly across the patient's thorax. The uninjured extremity and the operating table are draped with half sheets. The foot on the injured side is excluded from the field by draping with moist sterile towels, figure 186, 2. A sterile irrigating tray,³ figure 186, 3, is then placed beneath the injury and the skin is disinfected. Towels are then applied to limit the operative field to the traumatized area, figure 186, 4. Care is taken to place the ends of these towels on the irrigating tray so that fluid gravitates to the tray, whence it is drained through the rubber tubing to the kick pail. A laparotomy sheet is then applied and the wound is ready for excision or debridement, figure 186, 5. After all traumatized tissue and foreign bodies have been removed under a stream of running saline, sterile towels are stitched to the skin edge. A clean laparotomy sheet is applied over the whole field and the fracture is reduced with the aid of the fracture table. Various procedures for fixation of the fracture can then be performed in a fresh sterile field.

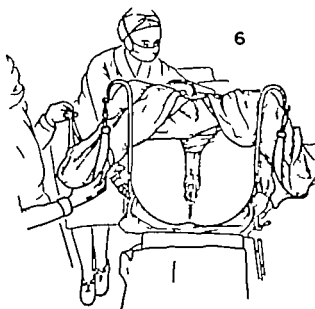
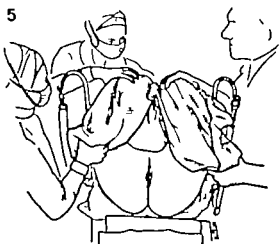
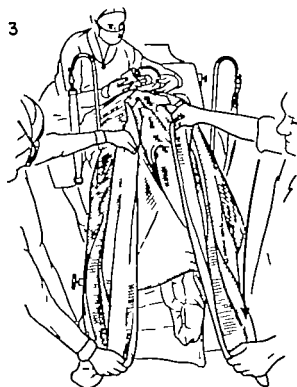
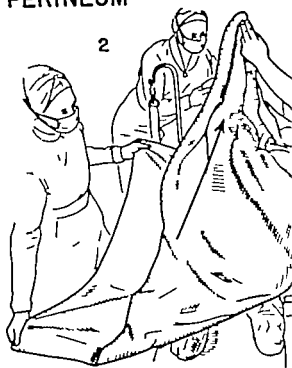
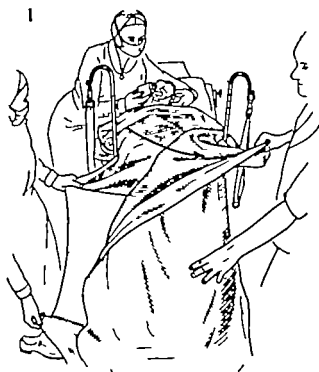
Figure 187 illustrates the exposure for operation upon the knee joint. The extremity is suspended by an assistant while the skin of the lower leg and thigh is thoroughly disinfected by means of a mechanical scrub, figure 187, 1. A large sphygmomanometer cuff is snugly applied as high as possible on the thigh. At this point, the cuff is inflated to occlude the vessels and a sterile towel, folded longitudinally, is applied over the cuff, figure 187, 2. With the unsterile assistant holding the heel, the sterile stockinette is rolled over the toes, figure 187, 2, and the toes are grasped by a sterile assistant while the stockinette is rolled up the leg and clipped to the sterile towel, figure 187, 3. The leg is then lowered

to the table which has been draped with sterile half sheets. A craniotomy sheet is then applied about the thigh to complete the draping of the operative field, figure 187, 4. The stockinette is split, figure 187, 5, with a scissors over the contemplated line of incision and after the skin and subcutaneous tissues have been incised, it is stitched to the cutaneous margins with a continuous silk suture, figure 187, 6, 7.

Perineal procedures are facilitated by proper positioning of the patient on the table and simple drapes which do not creep down over the operative field. The anesthetized patient is pulled down on the operating table so that the upper edge of the sacrum overlies the end of the split mattress. A doubled cotton blanket is the most convenient way of protecting the patient against exposure. The top corner of the upper leaf of the blanket is pulled to one side, figure 188, 1. The bottom corner is carried upward over the patient's abdomen, figure 188, 2. The corner which has been pulled to the side is then brought down over the foot, figure 188, 3, so that obliquely opposite corners of the blanket can now be used to cover the legs and feet, figure 188, 4. The patient is then grasped by the heels and the thighs are carefully flexed on the abdomen, figure 188, 5. The legs are raised over the stirrups and the thighs are abducted so that the knees can be propped around the stirrups, figure 188, 6. The stirrup straps are then adjusted so that one loop encircles the ankle above the heel, the other passing beneath the instep, figure 188, 7. In the lateral view, it will be noted that the patient is put in a position quite like that assumed when squatting, except that the patient is recumbent. Note that the buttocks overhang the break in the table completely so that redundant tissue falls away from the perineum, figure 189, 9. This position also presents the perineum in a plane facing

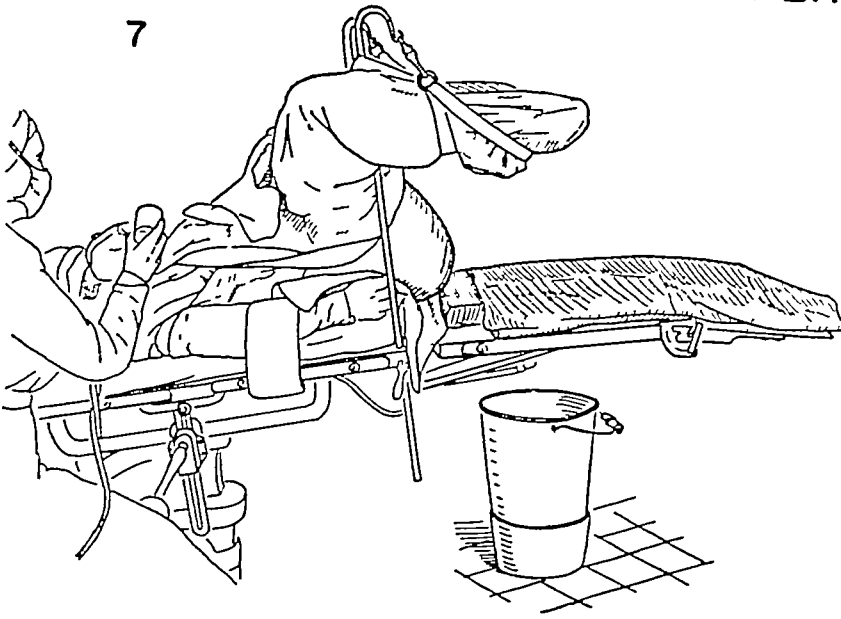
³ MARBLE, H. The Management of Hand Injuries, *J Indust Hyg & Toxicol*, 26: 189, 1944

EXPOSING PERINEUM

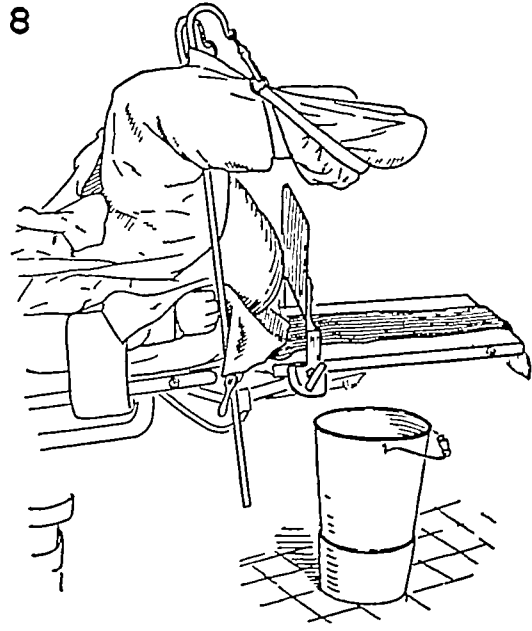


SCRUBBING PERINEUM

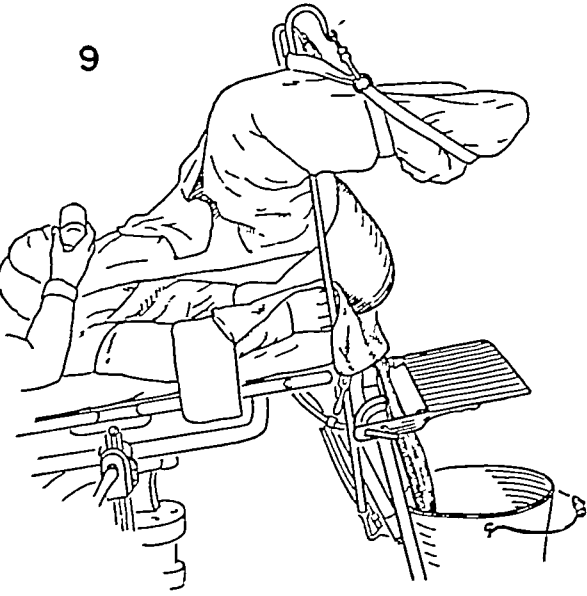
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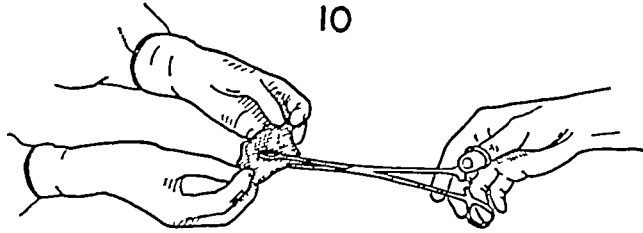
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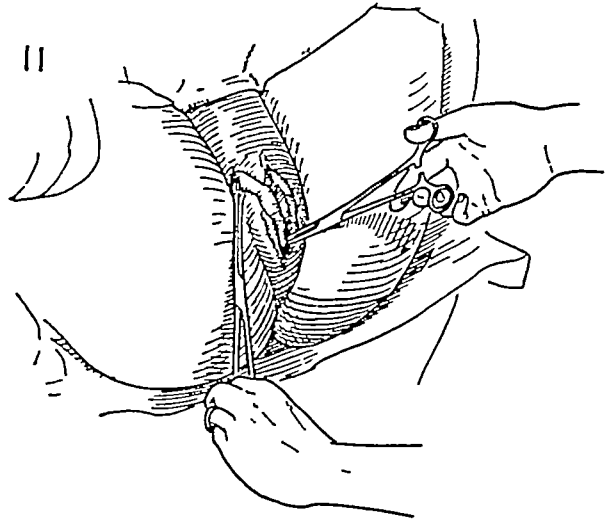
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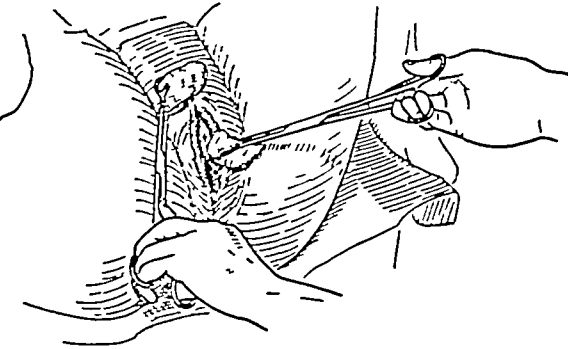
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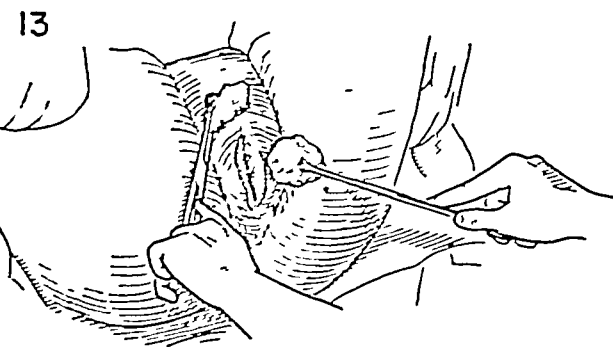
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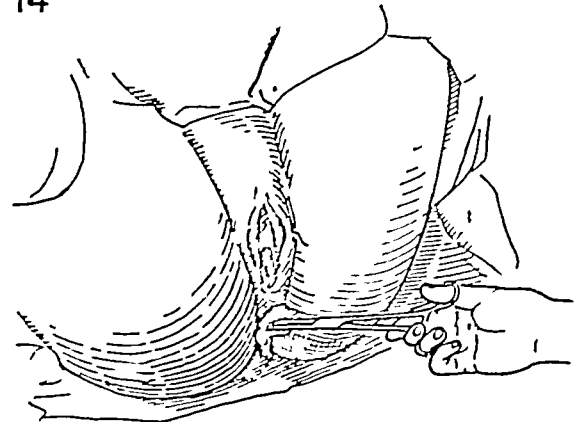
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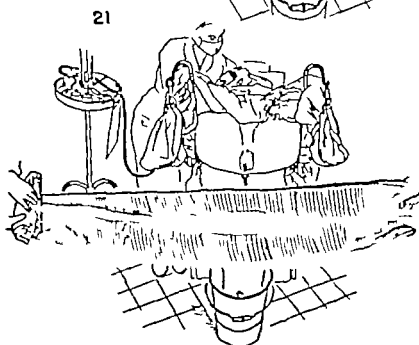
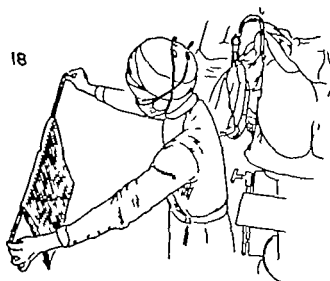
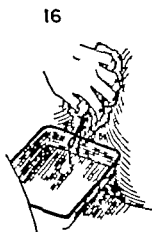
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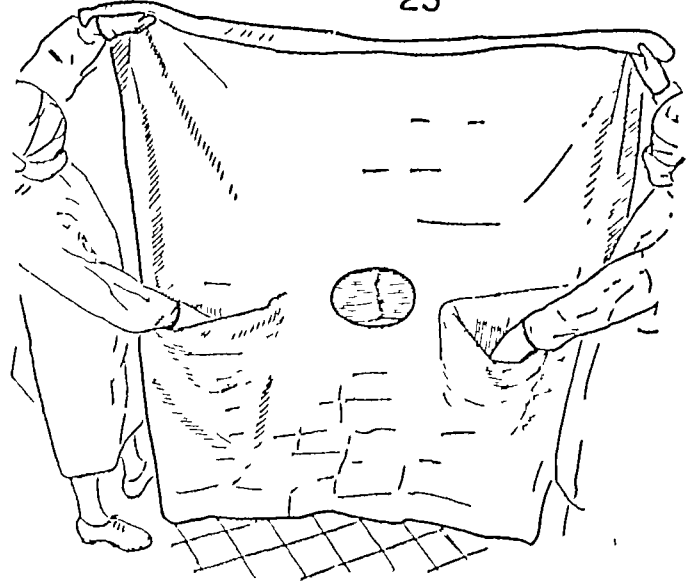
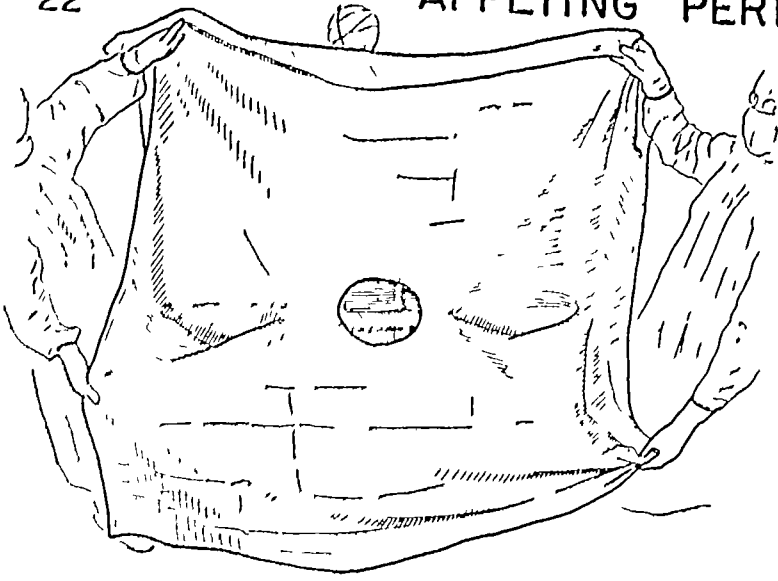
CATHETERIZING BLADDER — DRAPING



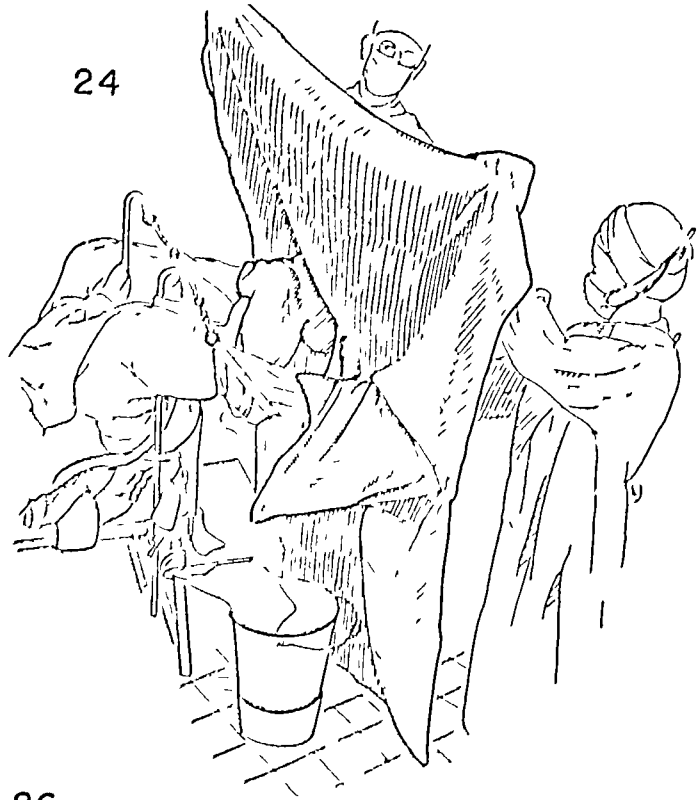
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APPLYING PERINEAL DRAPE

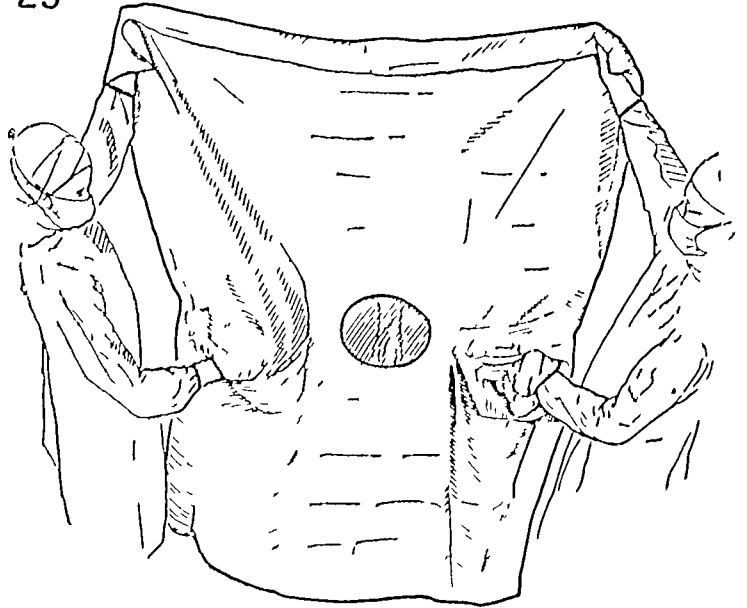
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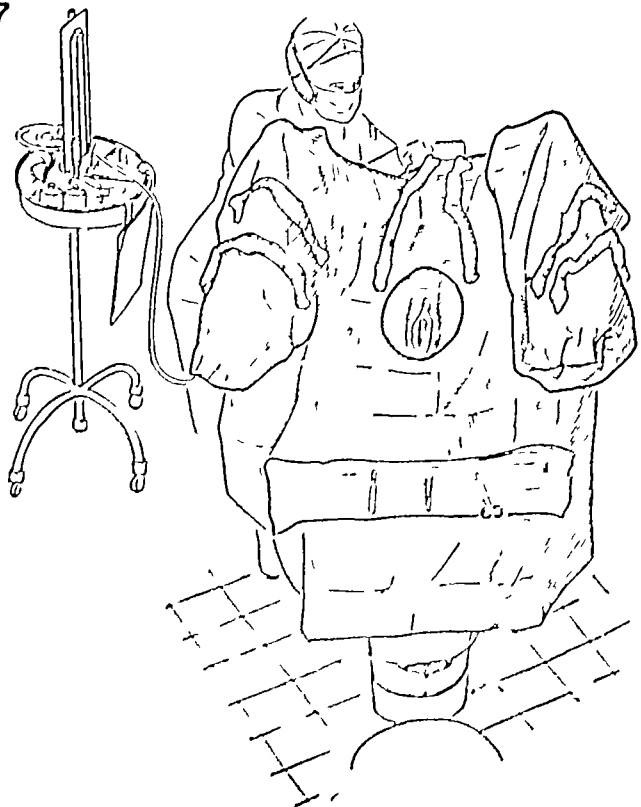
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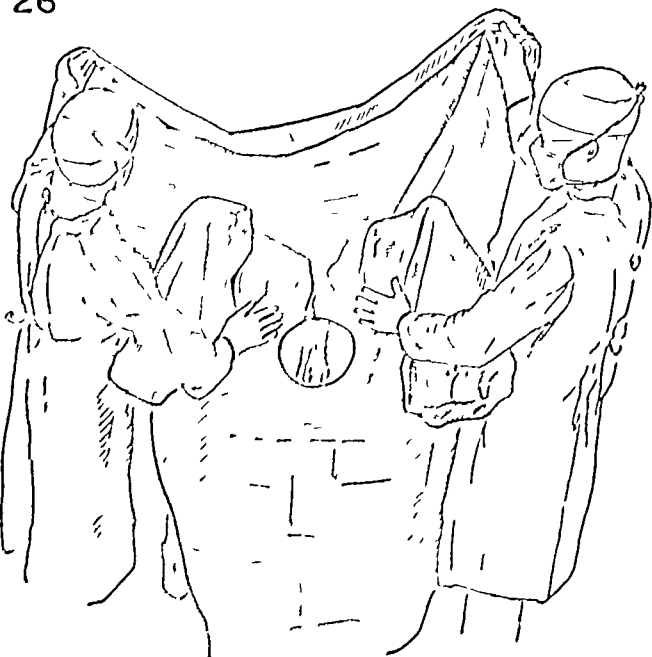
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27



26



obliquely upward rather than in a vertical plane which makes operative procedures difficult. This advantageous position can be accentuated by tilting the table. At this stage, the foot piece of the table is turned upward and fastened securely to the lower section, figure 189, 8, of the table to serve as a shelf when the table is broken, figure 189, 9. Note that the Kelly pad has been located in its proper position beneath the mattress so that it is simply uncovered in the operating room and time is not wasted while it is put into position. Fig 189, 8

Experience has shown that disinfection of the vulva, perineum, and vagina must be made the responsibility of a trusted member of the surgical team. Some surgeons insist upon performing the catheterization themselves. A sterile towel is cuffed beneath the blanket over the patient's abdomen and a second towel is inserted between the buttocks and the mattress. The area to be disinfected is scrubbed with knotted sponges, clamped in sponge sticks, figure 189, 10. The procedure is quite similar to that performed on the abdomen. Six changes of sponges, saturated alternately with 70% alcohol and 1:1000 aqueous Zephiran, are used. The introitus, vagina, figure 189, 11, labia minora, figure 189, 12, prepuce, and the vulva, figure 189, 13, are cleansed in that order. Finally, the perineum and the perianal skin are scrubbed before the sponges are discarded, figure 189, 14. The patient is then catheterized, figure 190, 15. 16 Following catheterization, a sterile towel is draped transversely across a strip of two centimeter adhesive held taut by the circulating nurse, figure 190, 17, 18. This towel is then fastened across the buttocks and

clipped to the fourchet, figure 190, 19, exclude the anus from the field. The sheet is then applied. The rolled edges grasped, figure 190, 20, and opened figure 190, 21. The upper edge of the sheet is held taut and the fan folding is shaken so that the pockets for the legs pout out, figure 191, 22. The free arms of the sheet and assistant are passed into these pockets, figure 191, 23, the toes are grasped, figure 191, 24, and the pockets are closed, figure 191, 25, as the sheet is drawn over legs, stirrups, and thighs, figure 191, 26. The sheet is then smoothed over the patient, figure 191, 27, to fit the field snugly. A moistened folded towel is draped across the patient's chest.

INSECTS IN THE OPERATING ROOM

The operating room must be sprayed with an insecticidal aerosol when it is closed the night during the season of the year when insects are prevalent. Aerosols containing a solution of pyrethrum and oil in freon⁴ are most effective. Small rooms containing insecticide should be used to kill flies that get into the operating room while an operation is being done. Swatters scatter too many organisms to be safe.

Cockroaches and silver fish are common causes for contamination of sterile supplies during storage. They must be searched methodically in every hospital. Treatment with DDT (dichloro-diphenyl-trichloro-ethane) will render premises insect repellent for weeks.⁵

⁴ EAGLESON, CRAIG U. S. Patent 2,209,145 (1941)

⁵ GOODRICH, L. D. Insecticidal Aerosols, *Pests and Their Control* 11:12, 1943

obliquely upward rather than in a vertical plane which makes operative procedures difficult. This advantageous position can be accentuated by tilting the table. At this stage, the foot piece of the table is turned upward and fastened securely to the lower section, figure 189, 8, of the table to serve as a shelf when the table is broken, figure 189, 9. Note that the Kelly pad has been located in its proper position beneath the mattress so that it is simply uncovered in the operating room and time is not wasted while it is put into position. Fig 189, 8

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clipped to the fourchet, figure 190, 19, to exclude the anus from the field. The perineal sheet is then applied. The rolled edges are grasped, figure 190, 20, and opened out, figure 190, 21. The upper edge of the sheet is held taut and the fan folding is shaken out so that the pockets for the legs pout open, figure 191, 22. The free arms of the nurse and assistant are passed into these pockets, figure 191, 23, the toes are grasped, figure 191, 24, and the pockets are everted, figure 191, 25, as the sheet is drawn over the legs, stirrups, and thighs, figure 191, 26. The sheet is then smoothed over the abdomen, figure 191, 27, to fit the field snugly. A moistened folded towel is draped across the shelf.

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⁴ EAGLESON CRAIG U. S. Patent 2,209,145 (1941)

⁵ GOODRICH L. D. *Insecticidal Aerosols, Pyres and Their Control* 11:12, 1943

CHAPTER XV

TERMINAL STERILIZATION OF INSTRUMENTS AND TEXTILES FROM SEPTIC CASES

The central salt solution bowls, used on so many operating tables to wash and wipe instruments is the most common unrecognized distributing focus in an otherwise aseptic technic. Instruments coming out of the wound should be discarded and resterilized; not touched, wiped or polished.

— ALLEN O WHIPPLE, 1940¹

Many technics have been devised for the terminal sterilization of dangerous organisms encountered during the course of an operation. Most of these are as unreliable bacteriologically as they are time-consuming. The problem is to confine the dangerous bacteria to the areas contaminated during the operation and to destroy them as quickly as possible without spreading them throughout the operating suite. The technic to be described has been elaborated to enable the scrub nurse to care for the terminal disinfection singlehanded. It causes no inconvenience to any other member of the team, so that expediency does not prompt breaks in technic. It is not time-consuming. It is so simple that fifteen minutes is adequate for carrying it through in detail and the instruments and operating room are again ready for use within twenty-five minutes. The technic has been in use for nine years. During that period, no distinction has been made between "clean" and "septic" cases. Hemorrhoidectomy, incision and drainage of abscesses, and the like are scheduled indiscriminately with

herniorrhaphy, radical mastectomy, or thyroidectomy with complete success.

By definition, every case where pus or gangrene is encountered, compounded injuries or operations upon the intestinal tract or perineum are "dirty" and the linen and instruments must be disposed of by the following "dirty case technic."

As the operation draws to a close, the circulating nurse wheels in a truck fitted with two duck bags and all the supplies and equipment necessary for the safe disposal of contaminated instruments and linen. No one on the operating team other than the scrub nurse is inconvenienced by the technic. The only difference from a clean case is that the other members of the team are asked to seek assistance in removing their gowns. At the close of the operation, it is the duty of every member of the surgical team to thoroughly cleanse the outside of his gloves in the glove basin. This is quickly and easily done with the gloves on the hands but is a time-consuming and messy chore when the soiled gloves are taken off and left for others to clean. Gloves should be removed habitually by a technic which avoids contamination of the skin of the hands and arms. Such a technic is manda-

¹ WHIPPLE, A. O. *Essential Principles in Clean Wound Healing, Surg., Gyn. & Ob.*, 70:257, 1949. By permission of *Surgery, Gynecology & Obstetrics*.

tory when dangerous organisms have been encountered at operation and is desirable when the surgeon intends to enter a second operation without scrubbing his skin a second time. The cuffs of the gloves are turned back enough to liberate the sleeves of the gown, figure 192, 1, 2, 3. The circulating nurse loosens the ties at the back of the gown, figure 192, 4. Facing the surgeon, she grasps the shoulder seams of the gown, figure 192, 5, and pulls it off the arms so that the sleeves turn inside out as they are removed, thereby avoiding contamination of the skin of the arms with the inside of the gown. The gown is rolled up and discarded in the laundry bag on the right end of the truck, figure 193, 1. The gloves are then removed as shown in figure 192, 7 to 10. The hands of the team are prepared for the next operation simply by submerging them in the same germicidal solution which was used for preoperative disinfection and rubbing every area of the skin thoroughly for two minutes.

After assisting the members of the team out of their gowns, the circulating nurse's first duty is to ready the dirty case truck for the scrubbed nurse, figure 193, 1. A sterilizer bucket is placed on the instrument table, figure 193, 2. The guard is removed from the second sterilizer bucket, figure 193, 3, and is placed in the center of the truck, figure 193, 5. The bucket is put on the nurse's table, figure 193, 4. A needle box is taken from the top drawer, figure 193, 5, and dropped on the nurse's table, figure 193, 6. Washed gauze from the same drawer is put into the pail on the truck, figure 194, 7, 8. A clean pair of gloves is put on the left hand corner of the truck, figure 194, 9, 10. The lids of the instrument pans are removed and propped against the back rail of the truck, figure 194, 11. Germicide, either 1 1000 aqueous Zephiran or 1 1000 sodium hypochlorite, is poured

into the bucket, figure 194, 12. A water proof paper bag, taken from the bottom shelf of the truck, figure 195, 13, is opened, the upper edge cuffed back and the bag placed upright on the floor, figure 195, 14. The scrubbed nurse, meanwhile, removes the instruments, sponges, and utensils from the operating field, turns back the drapes, rolls them up and drops them in the right-hand bag on the truck, figure 195, 15. If they are wet, she rolls them so that the dry portion about the periphery effectively covers the wet areas.

The dressing is then completed and the patient is wheeled from the room.

The instruments are opened and gathered into the sterilizer bucket on the instrument table, figure 195, 16. When this has been done, the bucket is put on the nurse's table and the drapes on the instrument table are rolled up and put into the laundry hamper, figure 195, 15. The instruments on the nurse's table are opened and collected into the bucket, figure 195, 17, 18. The needles are gathered into the needle box, figure 196, 19, which is placed in the bucket with the instruments. Unused tubes of surgical gut are immersed in the formaldehyde germicide, figure 196, 20, for disinfection. Bougies, Penrose tubing, and the like are placed in the 1 1000 solution of Zephiran. Both of the instrument pans are fitted with perforated plates which serve to keep the tubes, etc., submerged. Clean dry goods, such as unused gowns, towels, sponges, and sheets, are placed in the duck bag at the left hand corner of the truck, figure 196, 21. Soiled sponges are discarded into the waterproof paper bag, figure 196, 22. The surgical specimen is put into a waterproof bag held by the circulating nurse, who delivers it to pathology immediately, so that it is not unwittingly opened in the operating room. If the specimen is large, an amputated gangrenous

CHAPTER XV

TERMINAL STERILIZATION OF INSTRUMENTS AND TEXTILES FROM SEPTIC CASES

The central salt solution bowls, used on so many operating tables to wash and wipe instruments is the most common unrecognized distributing focus in an otherwise aseptic technic. Instruments coming out of the wound should be discarded and resterilized, not touched, wiped or polished

— ALLEN O. WHIPPLE, 1940¹

Many technics have been devised for the terminal sterilization of dangerous organisms encountered during the course of an operation. Most of these are as unreliable bacteriologically as they are time-consuming. The problem is to confine the dangerous bacteria to the areas contaminated during the operation and to destroy them as quickly as possible without spreading them throughout the operating suite. The technic to be described has been elaborated to enable the scrub nurse to care for the terminal disinfection singlehanded. It causes no inconvenience to any other member of the team, so that expediency does not prompt breaks in technic. It is not time-consuming. It is so simple that fifteen minutes is adequate for carrying it through in detail and the instruments and operating room are again ready for use within twenty-five minutes. The technic has been in use for nine years. During that period, no distinction has been made between "clean" and "septic" cases. Hemorrhoidectomy, incision and drainage of abscesses, and the like are scheduled indiscriminately with

herniorrhaphy, radical mastectomy, or thyroidectomy with complete success.

By definition, every case where pus or gangrene is encountered, compounded injuries or operations upon the intestinal tract or perineum are "dirty" and the linen and instruments must be disposed of by the following "dirty case technic."

As the operation draws to a close, the circulating nurse wheels in a truck fitted with two duck bags and all the supplies and equipment necessary for the safe disposal of contaminated instruments and linen. No one on the operating team other than the scrub nurse is inconvenienced by the technic. The only difference from a clean case is that the other members of the team are asked to seek assistance in removing the gowns. At the close of the operation, it is the duty of every member of the surgical team to thoroughly cleanse the outside of his gloves in the glove basin. This is quick and easily done with the gloves on the hand but is a time-consuming and messy chore when the soiled gloves are taken off and left for others to clean. Gloves should be removed habitually by a technic which avoids contamination of the skin of the hands and arms. Such a technic is manda-

¹ WHIPPLE, A. O. Essential Principles in Clean Wound Healing, *Surg., Gyn. & Ob.*, 70:257, 1940. By permission of *Surgery, Gynecology & Obstetrics*.

tory when dangerous organisms have been encountered at operation and is desirable when the surgeon intends to enter a second operation without scrubbing his skin a second time. The cuffs of the gloves are turned back enough to liberate the sleeves of the gown, figure 192, 1, 2, 3 The circulating nurse loosens the ties at the back of the gown, figure 192, 4 Facing the surgeon, she grasps the shoulder seams of the gown, figure 192, 5, and pulls it off the arms so that the sleeves turn inside out as they are removed, thereby avoiding contamination of the skin of the arms with the inside of the gown. The gown is rolled up and discarded in the laundry bag on the right end of the truck, figure 193, 1 The gloves are then removed as shown in figure 192, 7 to 10 The hands of the team are prepared for the next operation simply by submerging them in the same germicidal solution which was used for preoperative disinfection and rubbing every area of the skin thoroughly for two minutes

After assisting the members of the team out of their gowns, the circulating nurse's first duty is to ready the dirty case truck for the scrubbed nurse, figure 193, 1 A sterilizer bucket is placed on the instrument table, figure 193, 2 The guard is removed from the second sterilizer bucket, figure 193, 3, and is placed in the center of the truck, figure 193, 5 The bucket is put on the nurse's table, figure 193, 4 A needle box is taken from the top drawer, figure 193, 5, and dropped on the nurse's table, figure 193, 6 Washed gauze from the same drawer is put into the pail on the truck, figure 194, 7, 8 A clean pair of gloves is put on the left hand corner of the truck, figure 194, 9, 10 The lids of the instrument pans are removed and propped against the back rail of the truck, figure 194, 11 Germicide, either 1 1000 aqueous Zephuran or 1 1000 sodium hypochlorite, is poured

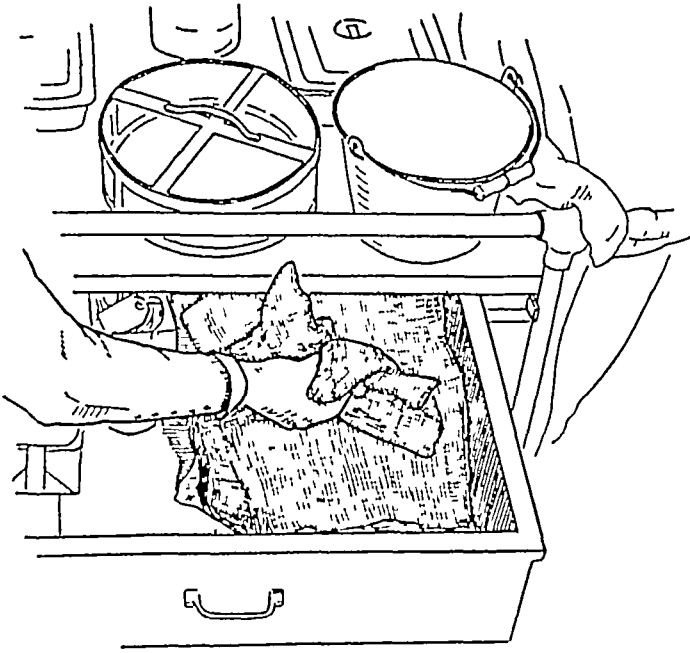
into the bucket, figure 194, 12 A waterproof paper bag, taken from the bottom shelf of the truck, figure 195, 13, is opened, the upper edge cuffed back and the bag placed upright on the floor, figure 195, 14 The scrubbed nurse, meanwhile, removes the instruments, sponges, and utensils from the operating field, turns back the drapes, rolls them up and drops them in the right-hand bag on the truck, figure 195, 15 If they are wet, she rolls them so that the dry portion about the periphery effectively covers the wet areas.

The dressing is then completed and the patient is wheeled from the room

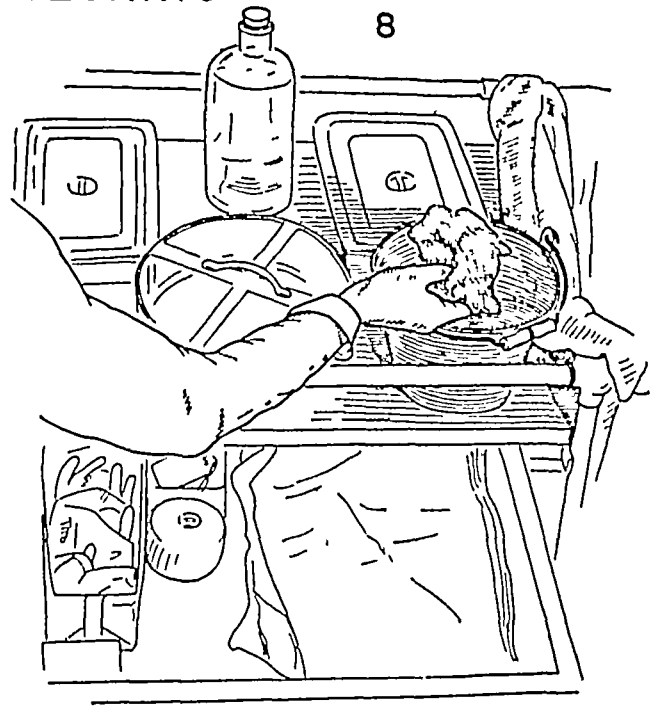
The instruments are opened and gathered into the sterilizer bucket on the instrument table, figure 195, 16 When this has been done, the bucket is put on the nurse's table and the drapes on the instrument table are rolled up and put into the laundry hamper, figure 195, 15 The instruments on the nurse's table are opened and collected into the bucket, figure 195, 17, 18 The needles are gathered into the needle box, figure 196, 19, which is placed in the bucket with the instruments Unused tubes of surgical gut are immersed in the formaldehyde germicide, figure 196, 20, for disinfection. Bougies, Penrose tubing, and the like are placed in the 1 1000 solution of Zephiran. Both of the instrument pans are fitted with perforated plates which serve to keep the tubes, etc., submerged Clean dry goods, such as unused gowns, towels, sponges, and sheets, are placed in the duck bag at the left hand corner of the truck, figure 196, 21 Soiled sponges are discarded into the waterproof paper bag, figure 196, 22 The surgical specimen is put into a waterproof bag held by the circulating nurse, who delivers it to pathology immediately, so that it is not unwittingly opened in the operating room. If the specimen is large, an amputated gangrenous

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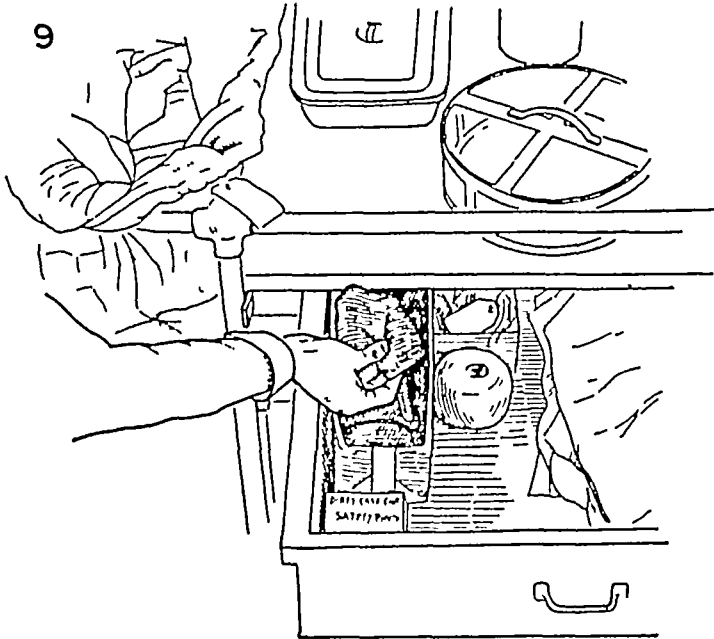
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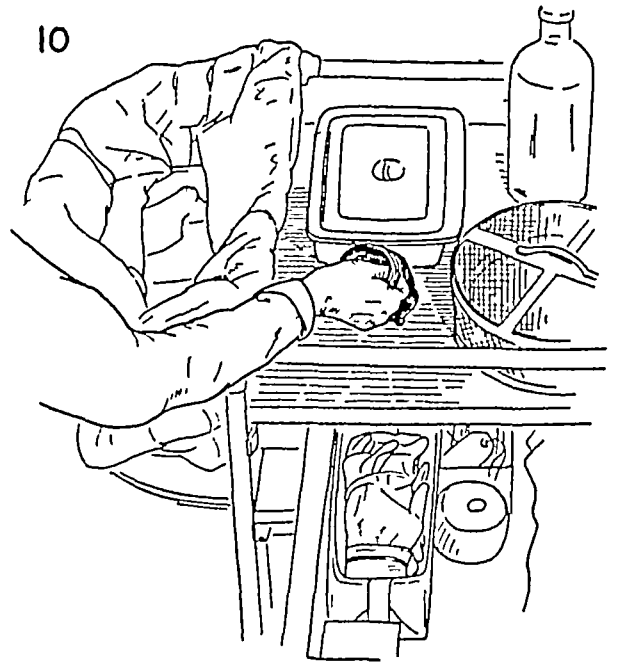
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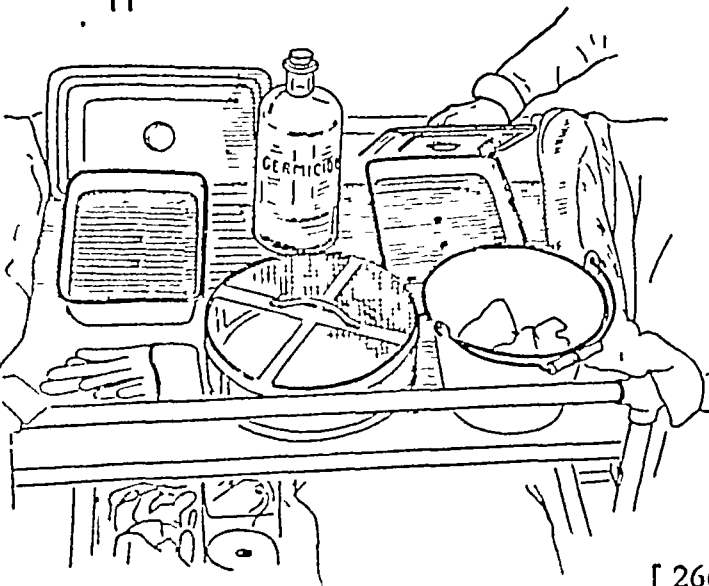
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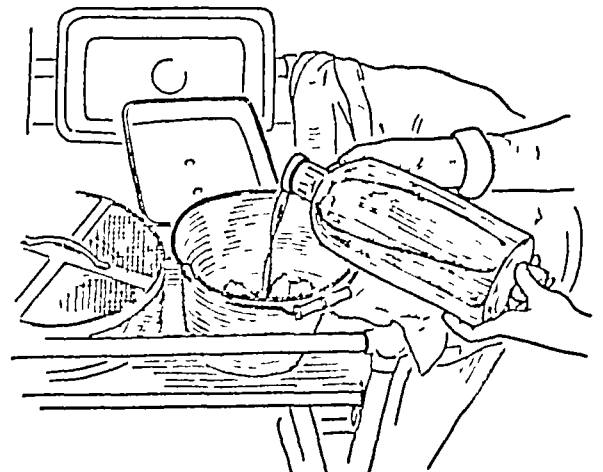
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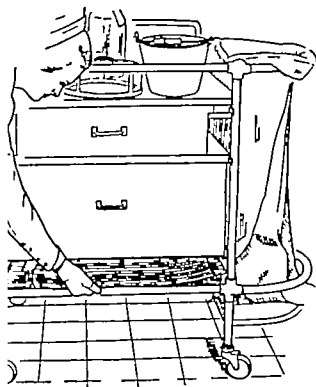
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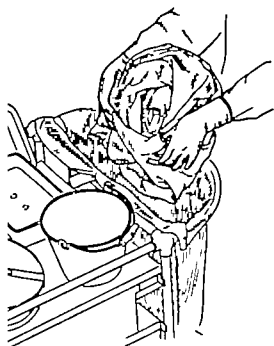
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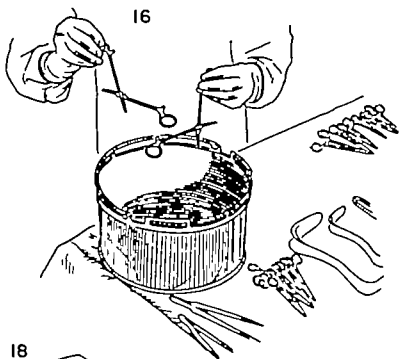
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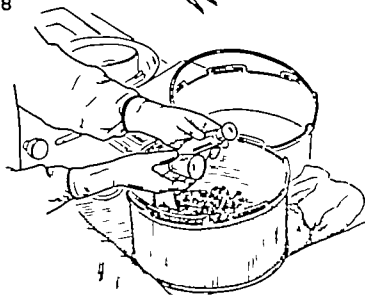
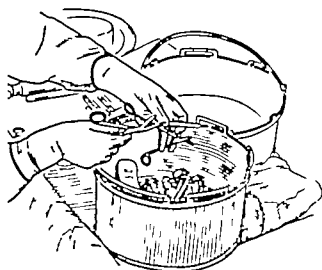
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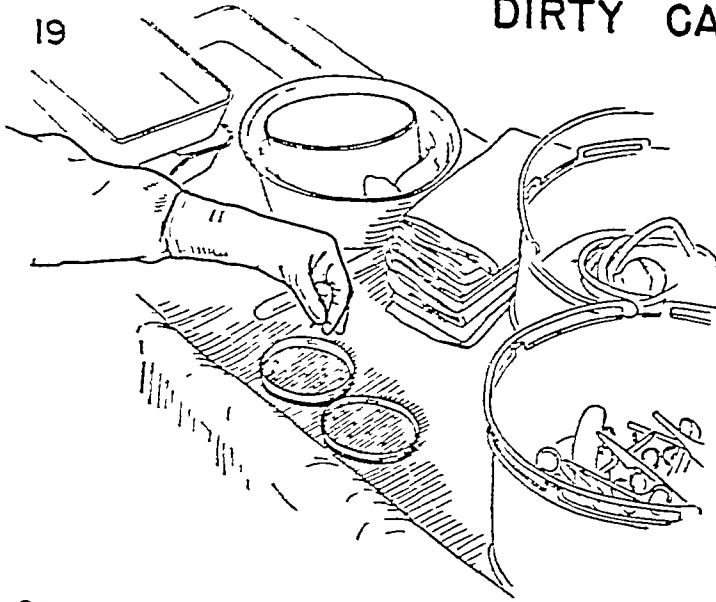


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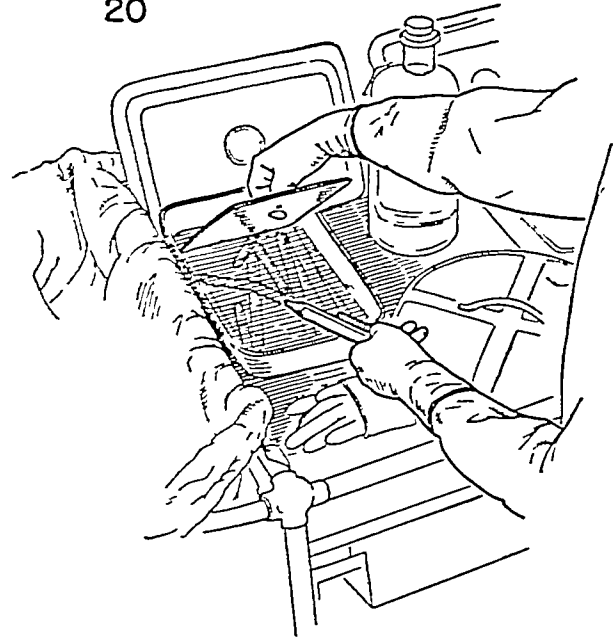


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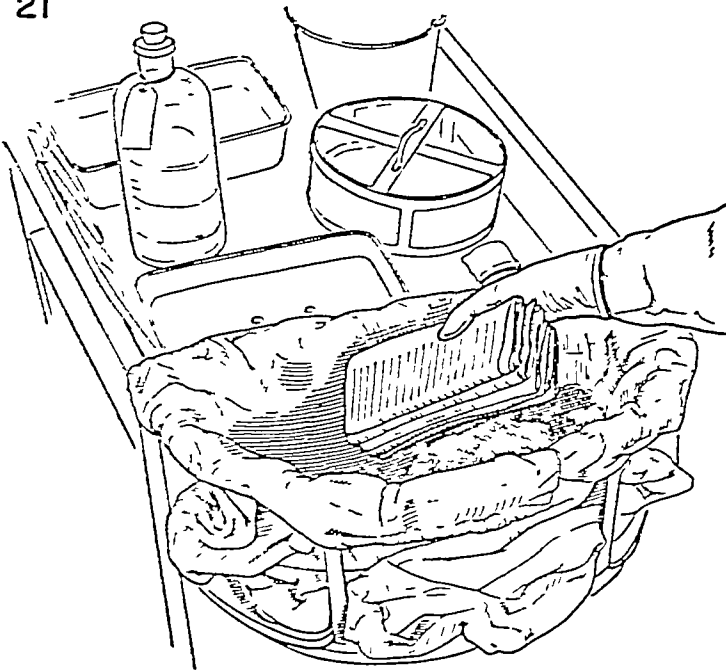
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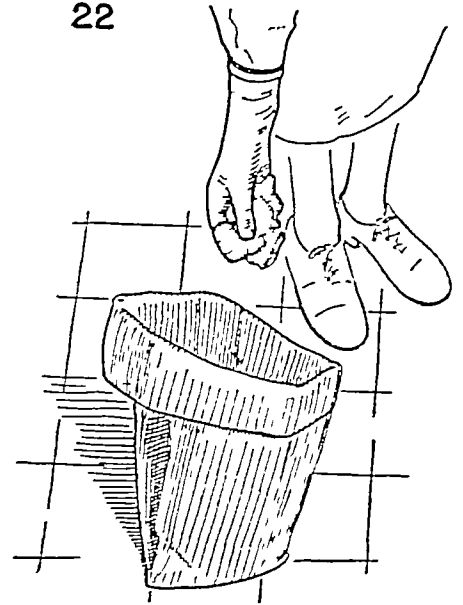
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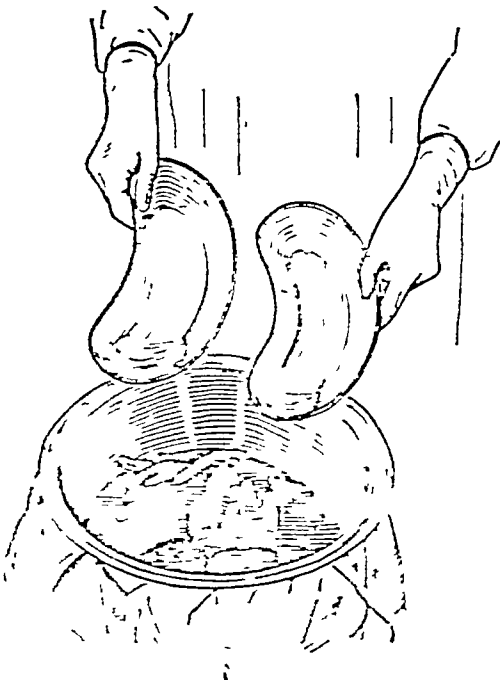
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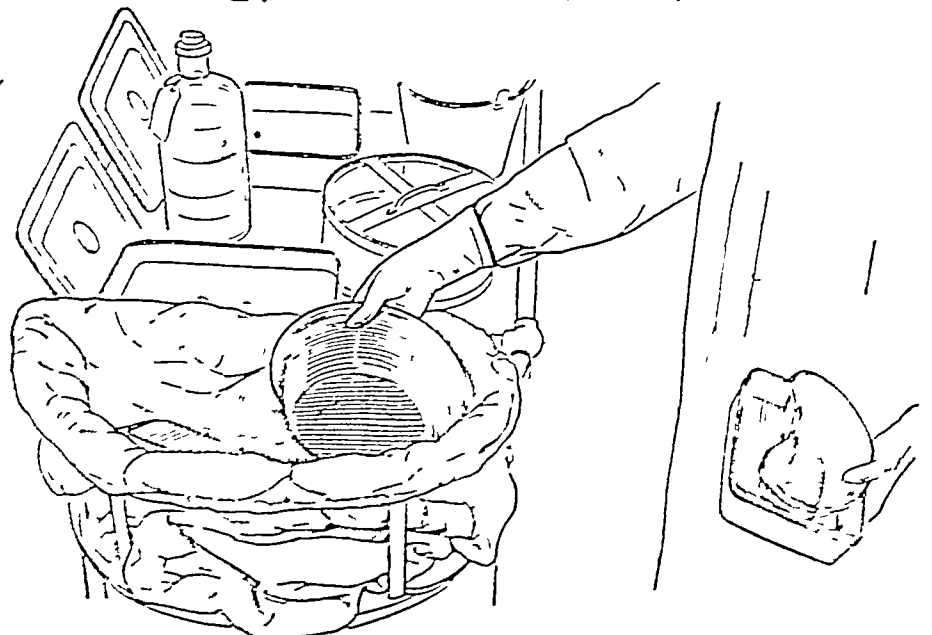
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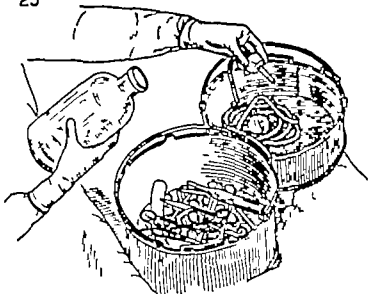


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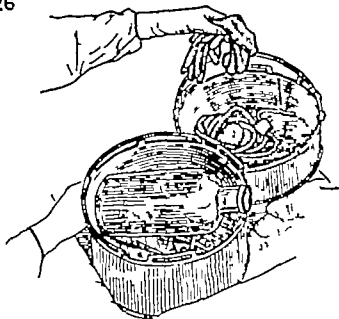


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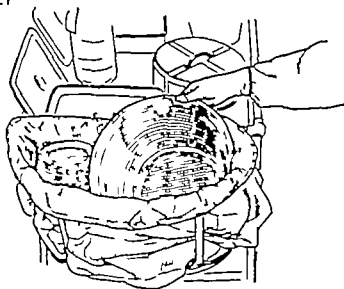
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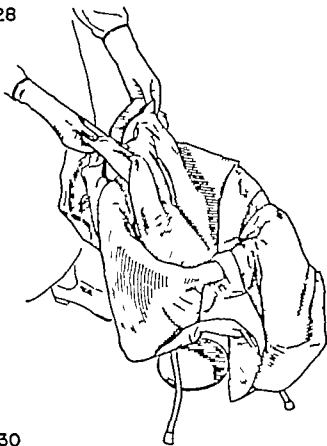
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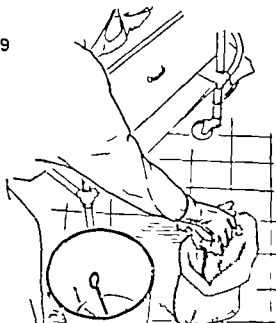
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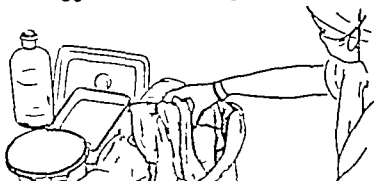
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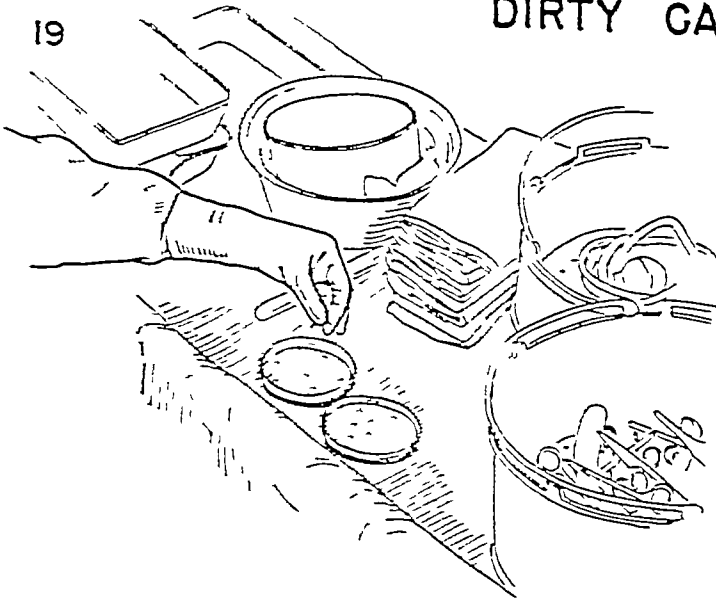


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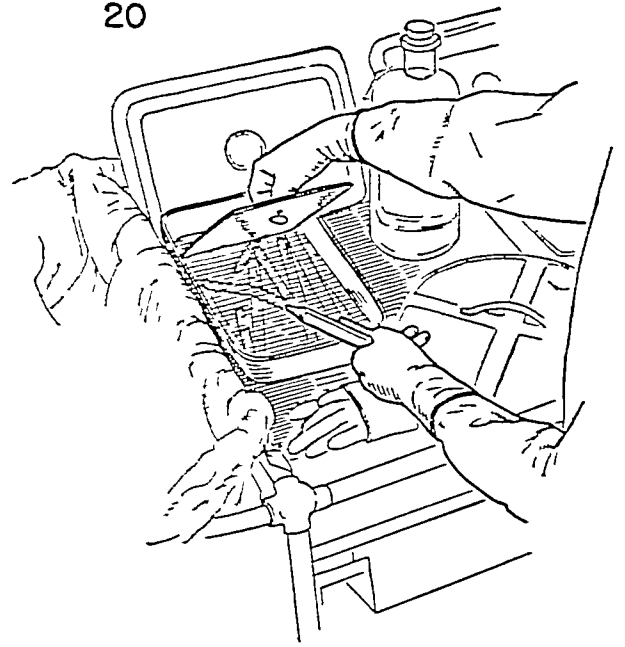


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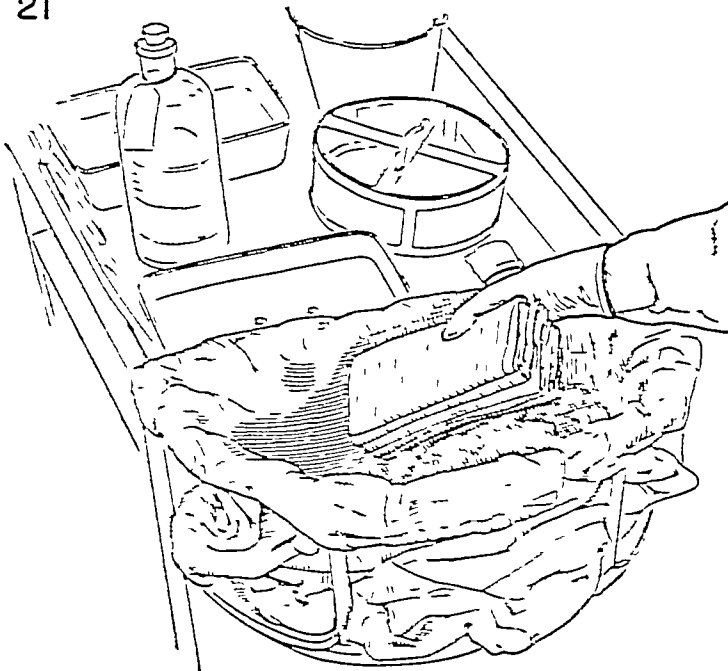
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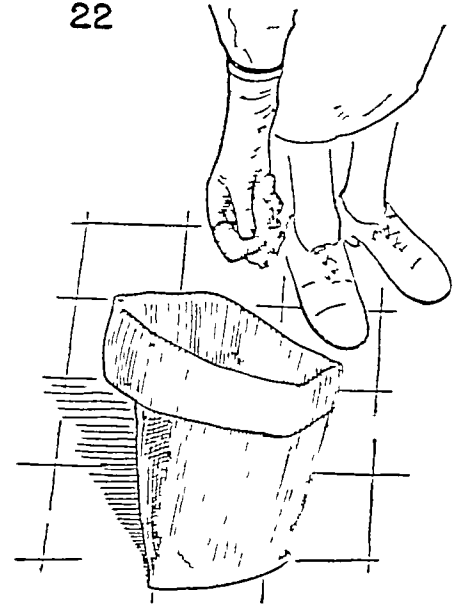
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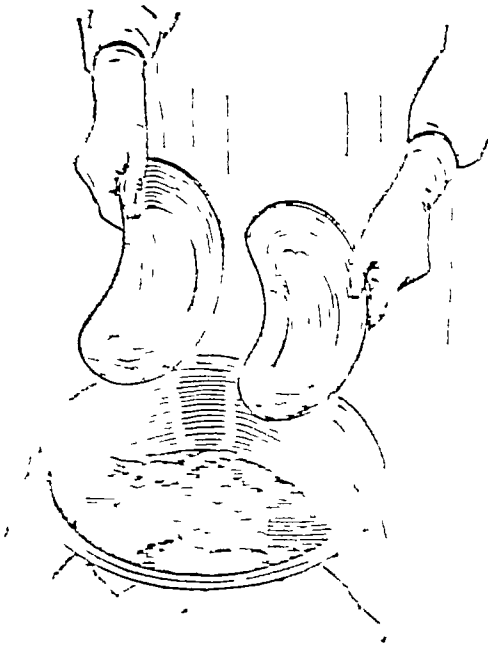
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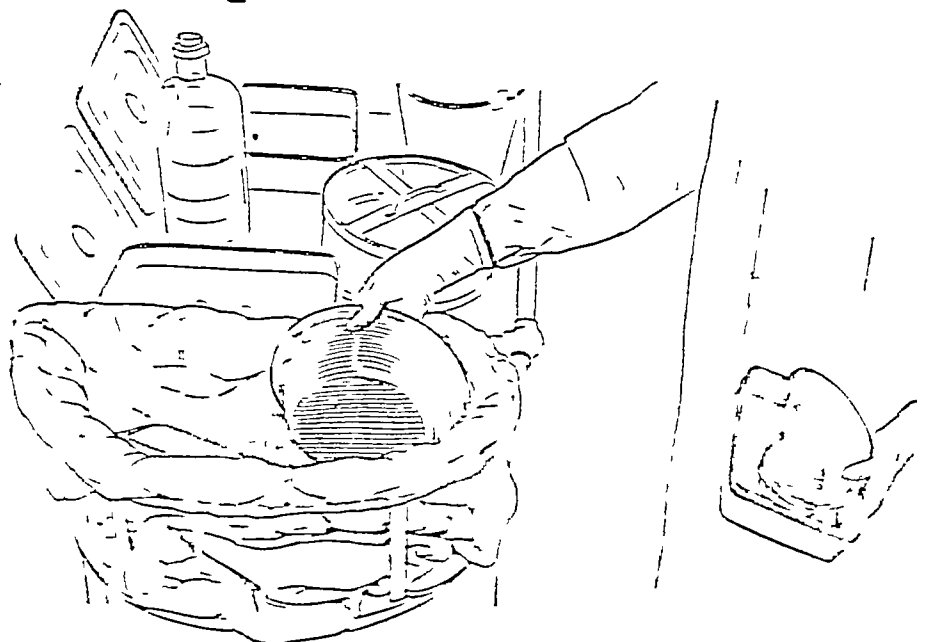
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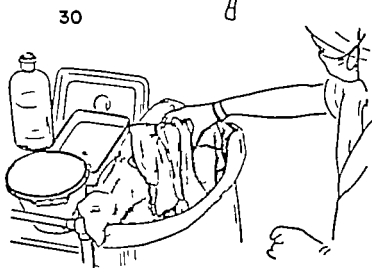
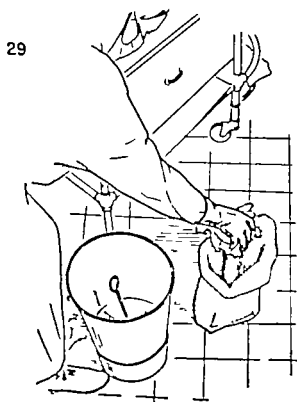
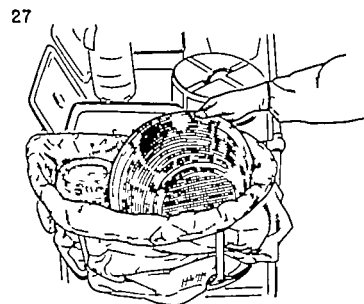
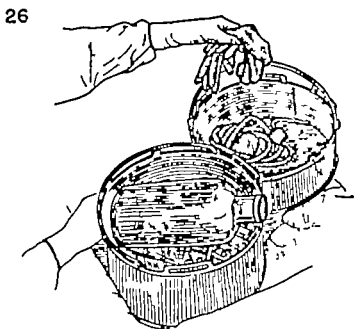
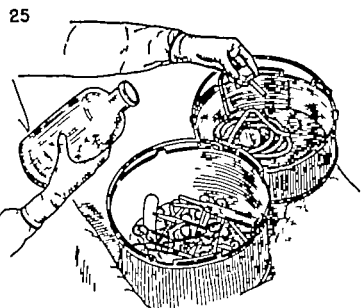
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DIRTY CASE TECHNIC



extremity, for example, the circulating nurse receives it in a sterile half sheet and carries it to the laboratory without contaminating herself. The fluid in the kidney basins and saline basin is poured into the glove basin, figure 196, 23, and the utensils are put into the left-hand bag, figure 196, 24. The stopper is removed from the suction bottle and the coiled rubber tubing is placed in the second sterilizing bucket along with the stopper, figure 197, 25. The contents of the suction bottle are emptied into the kick pail. The gloves are taken out of the glove basin, drained, and put into the second bucket along with the other rubber goods, figure 197, 26. The glove basin is emptied into the kick pail and then slipped into the left-hand bag, figure 197, 27. The drape is removed from the ring stand, figure 197, 28, rolled up and put into the right-hand bag, figure 195, 15. The soiled sponges, torn rubber gloves, etc., are taken out of the kick pail, squeezed dry, and put into the paper bag, figure 197, 29. The nurse is then helped out of her gown. The gown is folded and put into the right-hand bag, figure 197, 30. The kick pail is carried to the hopper and its contents disposed of, figure 198, 31.

The circulating nurse adds the proper quantity of detergent to the instrument washer sterilizer, figure 198, 32. The suction bottle is put on top of the instruments and the bucket is carried to the sterilizer by the scrubbed nurse, figure 198, 33. The nurse also carries the bucket of rubber goods to the sterilizer and puts it on top of the one containing the instruments, figure 198, 34. She removes her gloves, figure 192, 7 to 10, and discards them into the uppermost bucket, figure 198, 35. She returns to the dirty case truck and puts on the clean pair of gloves, figure 198, 36.

The drapes on the nurse's table are then carefully folded by grasping the under side of

the sheet and folding the contaminated surfaces inward, figure 199, 37, 38. The sheet is rolled, figure 199, 39, and put into the right-hand hamper, figure 195, 15. The furniture is then washed with the germicide in the pail, figure 199, 40, 41. The laundry bag containing the soiled linen is closed and snugly tied, figure 199, 42. A red tag marked "communicable" is attached and the bag is sent to the laundry where it is kept until the end of the day when all the bags marked "communicable," which have accumulated, are treated together. The drawstring on the bag of utensils and clean dry goods is pulled taut and tied, figure 200, 43. This bag is sterilized with the next load of dry goods going through the dressing sterilizer.

If the operating table has been contaminated, it is returned to the operating room and the contaminated areas are thoroughly scrubbed with germicide. The kick pail is next washed thoroughly with germicide, figure 200, 44, and the gauze is discarded into the paper bag, figure 200, 45. The cuff of the paper bag is carefully turned in and the bag is closed snugly so that it can be safely taken to the incinerator, figure 200, 46, 47. The nurse then removes her gloves and discards them into the upper bucket in the instrument washer sterilizer, figure 200, 48. She gets the guard from the dirty case truck and fits it into the top bucket to prevent the rubber goods from floating during sterilization, figure 200, 49. Sterilization is accomplished as shown in figure 110.

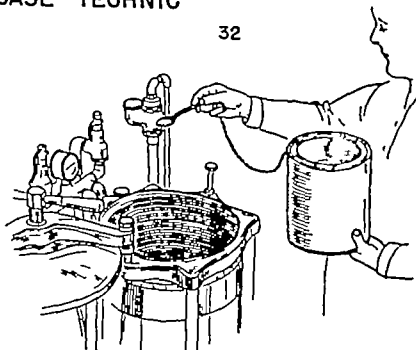
If the sterilizers are being used when the dirty operation is finished, things are cared for just as above to the stage where the buckets of instruments are placed in the sterilizer. Here an alternate technic is used. A large sheet of waterproof paper is spread on the instrument table and the buckets are placed on this paper, figure 201, 50, where they remain until the sterilizer is free. The bails of the buckets are then lifted with a

DIRTY CASE TECHNIC

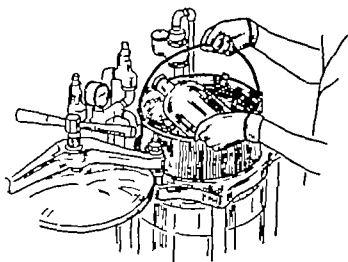
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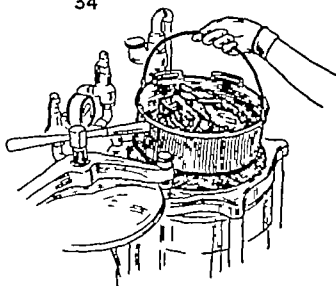
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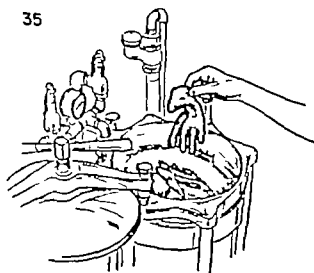
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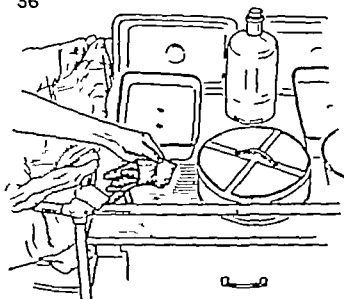
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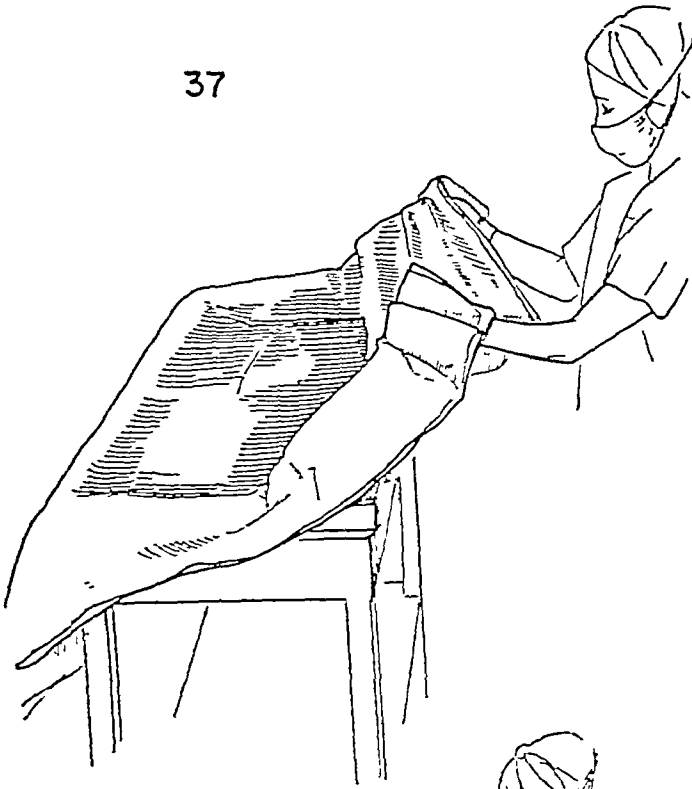


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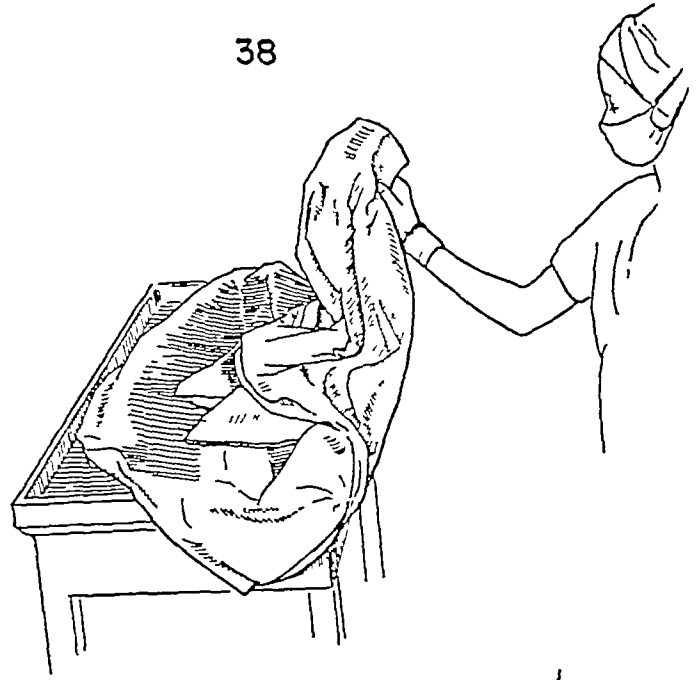


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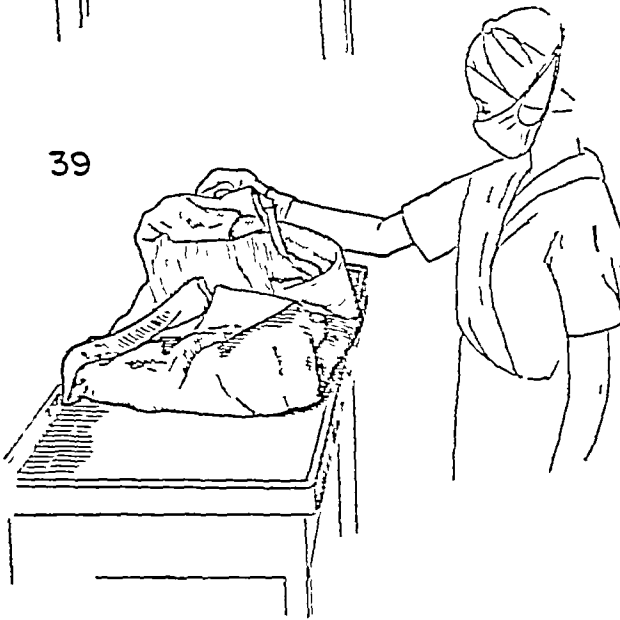
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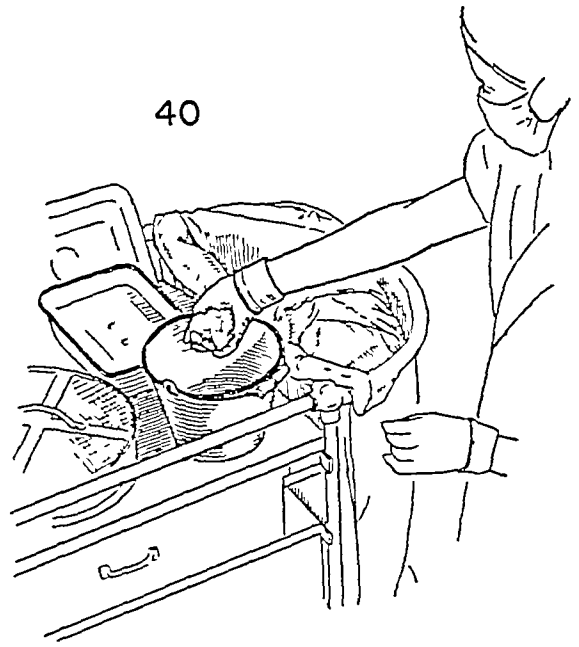
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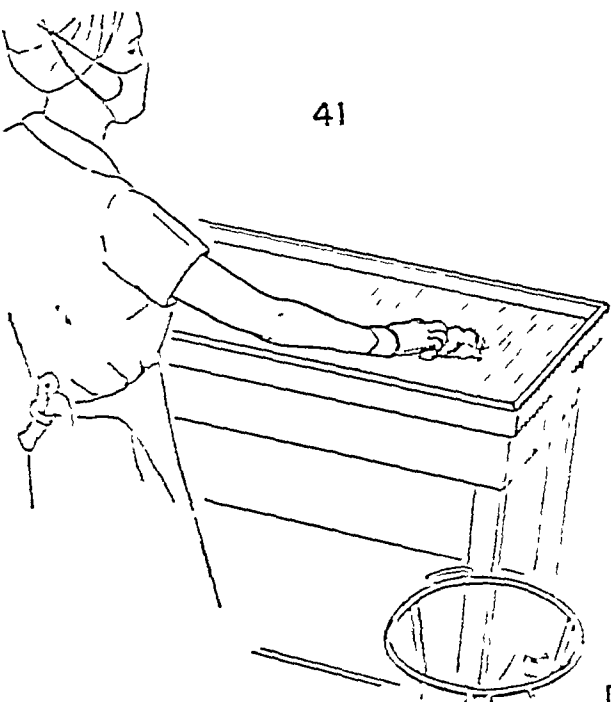
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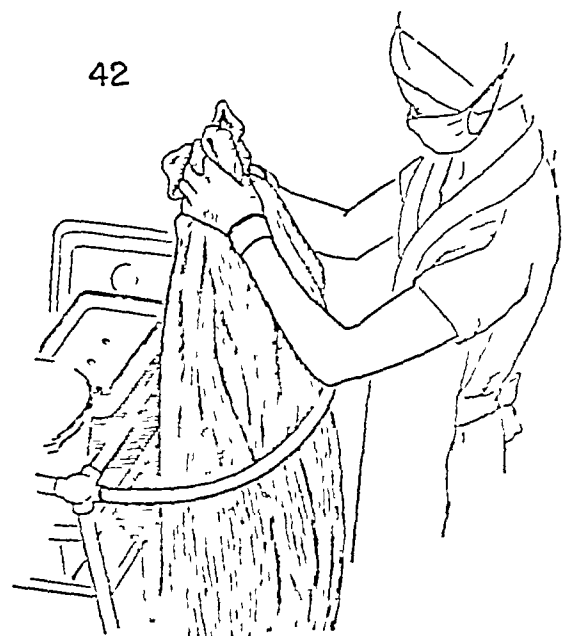
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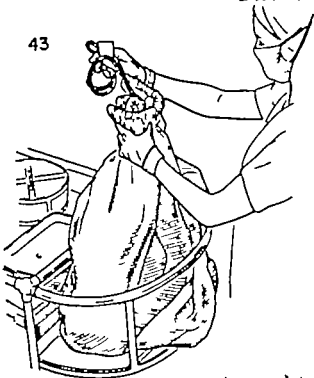


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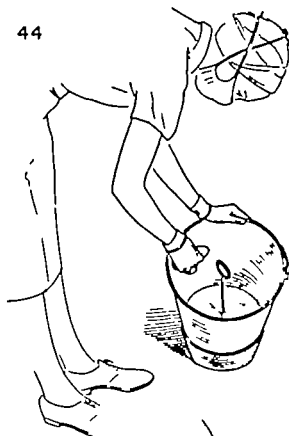


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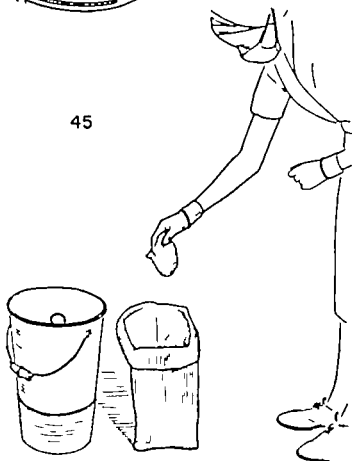
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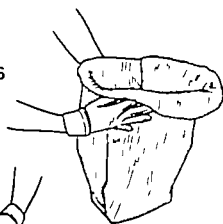
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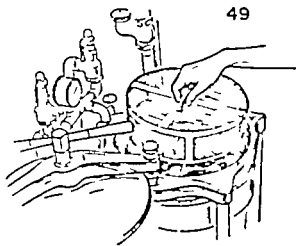
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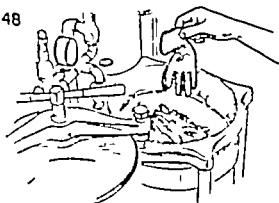
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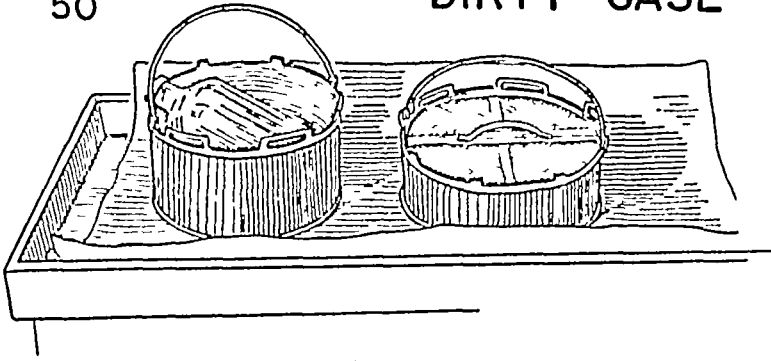


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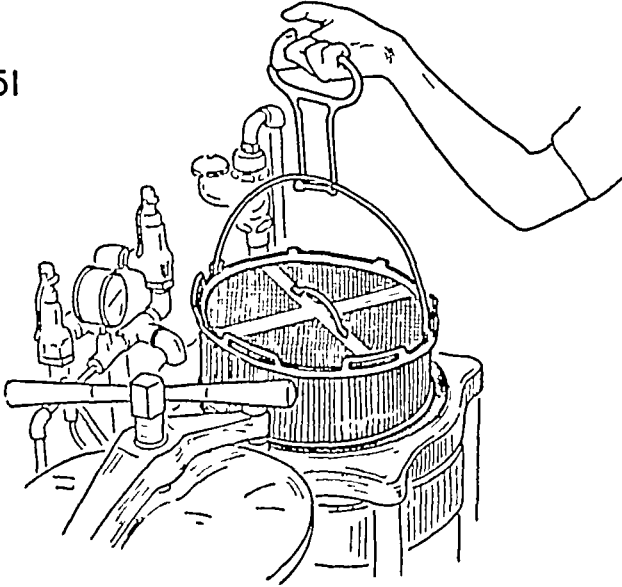


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DIRTY CASE TECHNIC



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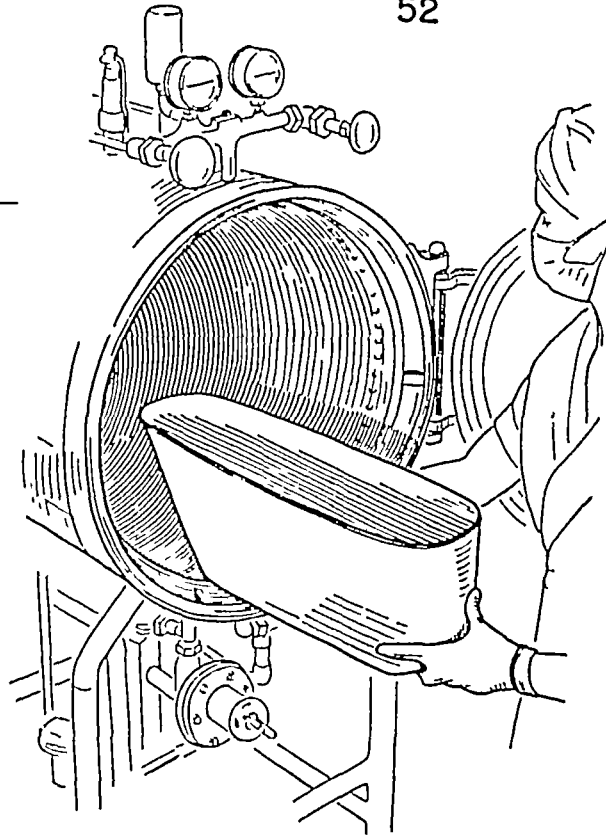


FIGURE 201

sterile handle, figure 201, 51, and the buckets are carried to the sterilizer. The handle is placed on top of the wire cage for sterilization

Lacking equipment such as that described, the instruments are gathered into an ordinary arm soak, figure 201, 52, and covered with a solution of cold 2% sodium triphosphate. The instruments are permitted to stand a few minutes to take the blood. They are then sterilized in saturated steam at 121°C for forty-five minutes. Rubber goods can be sterilized along with the instruments, if necessary, but it is preferable to sterilize them in a separate container because nickel plated instruments are likely to tarnish where they contact rubber during sterilization.

The sterilization of linen contaminated

with dangerous organisms is not difficult, provided the linen is not permitted to dry. Desiccation is deleterious because it fosters spore formation and hardens blood on the textile. The laundry bags marked "communicable" are emptied directly into a washing machine. The bags are thrown in also. The washing machine is filled with cold water and run for twenty minutes to leach out the proteins and to take blood stains. Water softener and soap are then added until there is a good head of lather. Three per cent excess soap is next added to provide a minimum pH of 11 to insure sterilization. The water is heated to boiling and soap is added a second time to make a good head of lather. The clothes are then rinsed and finished along with the other hospital laundry.

CHAPTER XVI

PREPARATION OF PARENTERAL FLUIDS

by the injection of water and salts (in quantities according to the previous extent of the evacuations) we may restore the deficient fluids of the body and bring back the blood to its normal state, thus removing a powerful cause of death and permitting the patient to recover from the disease

—WILLIAM B. O'SHAUGHNESSY, 1832¹

The parenteral administration of medicine has become so commonplace that everyone dealing with clinical problems should be familiar with the basic principles which determine its success. Regardless of the apparatus used or the type of solution prepared, there is no excuse for untoward reactions following routine parenteral therapy.²

Untoward reactions following the injection of sterile "distilled" water are characterized by symptoms suggestive of protein shock. The mild forms are evidenced merely by a moderate fever which reaches a peak and returns to normal within six hours following the infusion. In more severe reactions, hyperpyrexia follows chills or pain in the back or legs and usually occurs while the infusion is still flowing. Nausea, vomiting, and diarrhea may ensue, perhaps associated with a fall in blood pressure. In serious reactions, a marked drop in blood pressure is associated with cyanosis or circulatory collapse which may result in death. Mild reactions are distressing to the patients; severe reactions are dangerous, par-

ticularly since the indications for this form of therapy may present a patient already in critical condition. The cause of such reactions has been the subject of much conjecture despite clarifying laboratory and clinical evidence. Wechselsmann, in 1911, noted that distilled water acquired, on standing, the property of producing febrile reactions.³ He believed bacterial contamination responsible and advocated the administration of freshly distilled water only. Hort and Penfold, in 1911, confirmed Wechselsmann's observation that distilled water became contaminated with bacteria on standing.⁴ Removal of these bacteria by Berkefeld filtration did not eliminate the reactions. Thirteen types of bacteria were identified as capable of imparting the pyrogenic property to distilled water.

Seibert and her collaborators, 1923-1927,^{5, 6, 7} added other organisms to the

¹ WECHSELSMANN. *Neuere Erfahrungen über intravenöse Salzwasserinjektionen ohne Reaktionserscheinungen. Münchener Med. Wochenschr.*, 58:1510, 1911.

² HORT E. C. and PENFOLD W. J. *Dangers of Saline Injections, Brit. M. J.*, 2:1589, 1911.

³ SEIBERT F. B. *Fever-producing Substance Found in Some Distilled Waters, Am. J. Physiol.*, 6:190, 1923.

⁴ SEIBERT F. B. *Cause of Many Febrile Reactions Following Intravenous Injections, Am. J. Physiol.*, 7:1621, 1925.

¹ O'SHAUGHNESSY W. B. *Chemical Pathology of Cholera, Lancet*, 2:781, May 1832.

² WALTER C. W. *The Basis of Successful Parenteral Therapy U. S. A. M. Bull.*, 33:249-262, 1941.

list and were able to differentiate three groups of pyrogenic bacteria, those provoking low fever, those causing chills and high fever, and those responsible for immediate prostration and death. The etiologic factor was a filterable, thermostable, desiccation resistant exotoxin produced by various organisms capable of growing in distilled water. The contamination of distilled water was shown to be due to air-borne bacteria and/or a pyrogenic exotoxin carried from the raw water in the generator of the still to the condensers. Distillation in a still designed to prevent entrainment, immediate sterilization after distillation, and sealing to protect sterility were recommended as essential steps in providing safe water for parenteral injection. Another source of pollution of solutions was shown to be a pyrogenic exotoxin which dried on the inner surface of glassware. Flasks in which pyrogenic water had evaporated could be rendered safe by merely rinsing them with freshly distilled water.

Banks⁸ showed that pyrogens could be destroyed by heating water for thirty minutes at 140°C under 1950 mm gage pressure. CoTui and his co-workers^{9, 10} found that the pyrogen could be adsorbed on Sartz asbestos filters and estimated the size of the pyrogenic particle to be between 50 millimicrons and one micron. Pyrogenic

particles can also be adsorbed on activated charcoal.¹¹ These facts explain many difficulties encountered in parenteral administration, not only of electrolytes and dextrose but also of arsenicals, infiltration anesthetics, contrast media, and citrated blood or plasma.

There are but two requisites for a safe supply of parenteral solutions — a source of pure raw materials and centralized responsibility for cleanliness in the preparation of solutions and apparatus. Any hospital where major surgery is performed has the necessary sterilizing equipment and the trained personnel to whom such responsibility can be delegated.¹²

The quality of freshly distilled water is affected by two factors — the design of the still and the care and intelligence with which it is maintained and operated. Because those entrusted with the maintenance and/or operation of stills often have little concept of the process of distillation or what precautions must be taken to obtain pure distillate, various protective features have been incorporated into the design of stills. Water which has been distilled but once is sufficiently pure for intravenous work unless the water supply is unusually bad or the personnel is unreliable or shifted so often that no one is familiar with the proper operation of the still. Multiple distillation provides a factor of safety in such instances. However, a well designed still, intelligently operated and carefully maintained, can deliver in one distillation water as pure as that obtained by double or triple distillation.

⁷ SEIBERT, F. B. and MENDEL, L. B. Protein Fevers, with Special Reference to Casein, *Am J Physiol*, 67:105, 1923.

⁸ BANKS, H. M. Study of Hyperpyrexia Reaction Following Intravenous Therapy, *Am J Clin Path*, 4:260, 1934.

⁹ CoTui, F. W., McCLOSKEY, K. L., SCHRITT, M. and YATES, A. L. New Method of Preparing Infusion Fluids, Based on Removal of Pyrogen by Filtration, *JAMA*, 109:250, 1937.

¹⁰ CoTui, F. W. and WRIGHT, A. M. The Preparation of Nonpyrogenic Infusion and Other Intravenous Fluids by Adsorptive Filtration, *Ann Surg*, 116:412-425, 1942.

¹¹ LEES, J. C. and LEVY, G. A. Emergency Preparation of Pyrogen-free Water, *Brit M J*, 1:430-432, 1940.

¹² WALTER, C. W. The Relation of Proper Preparation of Solutions for Intravenous Therapy to Febrile Reactions, *Annals of Surgery*, 112:4, 1940.

DIAGRAMMATIC ELEVATION OF STILL

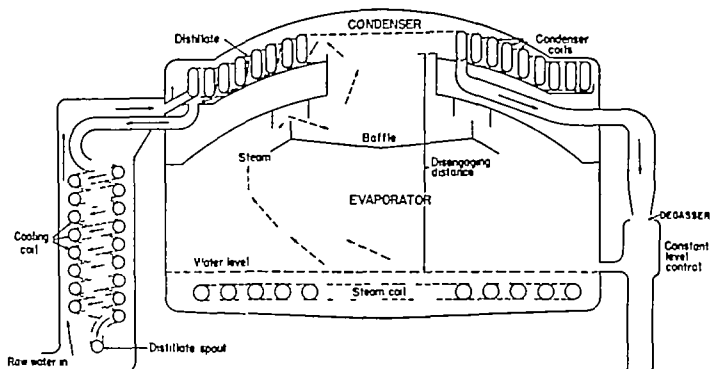


FIGURE 202

H. Alter

Diagrammatic elevations of the various types of stills in hospital use are illustrated in figures 202, 203, 204. Although the design varies, certain common elements may be noted. The source of heat must be accurately controlled to insure constant heat input; a steam coil is illustrated. Evaporator design must provide adequate space for the slow, vertical rise of steam to permit droplets, thrown from the agitated surface during the ebullition of steam, to fall back.

Condensers are usually lined with pure tin to resist attack by distilled water. Some of the aluminum alloys are also successful. The condensers of a well functioning still need never be cleansed. Indeed, cleansing is likely to introduce dirt or scratch the protective surface.

The chief cause of pollution of the distillate is entrainment of droplets of spray or foam thrown off by the boiling water. Thus, particles (bacteria) and/or solutes (pyro-

gens) are carried from the raw water in the evaporator to the condenser by the steam. Most stills are designed to eliminate entrainment. Properly placed baffles contribute much to the purity of the distillate by preventing pollution of the condensers with spray. Baffles eliminate entrainment by causing particles to impinge, thus removing them from the steam. The scrubbing action obtained by condensing a portion of the steam in a primary condenser is also helpful, figure 204. The partial chilling of the steam causes condensation to occur on small droplets, making them heavy enough to fall back.

Location of the condensers at a distance, preferably vertically, from the boiling surface provides opportunity for the droplets to disengage themselves from the flowing steam. The disengaging space must have a wide cross section so that the velocity of the steam is so low that entrainment is impossible.

DIAGRAMMATIC ELEVATION OF STILL

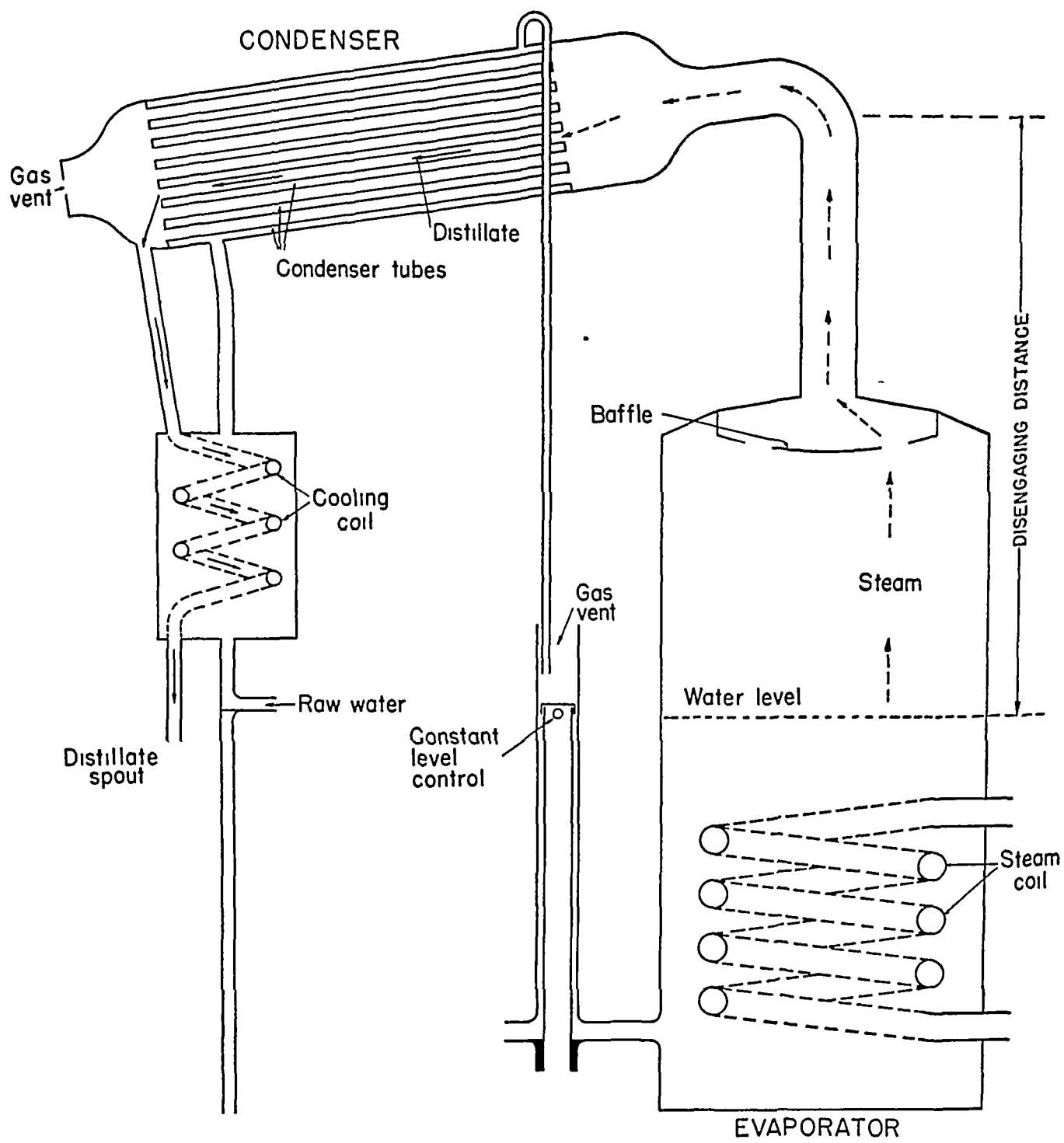


FIGURE 203

Waller²

Entrainment due to the foaming of hard water is often due to the concentration of residual impurities in the evaporator. A deconcentrator or bleeder permits continuous formation of steam from a flowing stream of water without harmful concentration of impurities.

Gross priming of a still is prevented by careful balancing of the flow of cooling water and the rate of heating. The water supply must be controlled to insure uniform flow of water through the evaporator, otherwise priming occurs whenever the water pressure drops. Too rapid heating causes explosive ebullition of steam and much splashing. The suddenly increased velocity of the stream of steam carries the splashed droplets past baffles or traps which are ordinarily effective. Because the dynamic pressures of water and steam supplies in most hospitals fluctuate widely, automatic control *at the still* must be relied upon to prevent priming; otherwise, the quality of the distilled water is not determined so much by the design of the still as it is by the number of times toilets are flushed, laundry machines are filled, or steam processing equipment is used. Pressure-reducing valves set at 75% of the static pressure of the steam and at 440 mm. Hg for water provide adequate control. Overloaded electrical circuits, a common fault in hospitals, may also influence the quality of the distillate, for if the still is adjusted while the voltage is low, it will prime when the voltage returns to normal and the heat input is increased.

Chemically pure distilled water cannot be stored unless it is hermetically sealed in sterile containers, hence, distilled water must be collected in a storage tank just large enough to accumulate a working supply. An inverted Pyrex carboy, fitted with a glass stopcock is best, figure 210 / because it can be drained dry. Carboys must be drained as soon as there is no imme-

DIAGRAMMATIC ELEVATION OF STILL

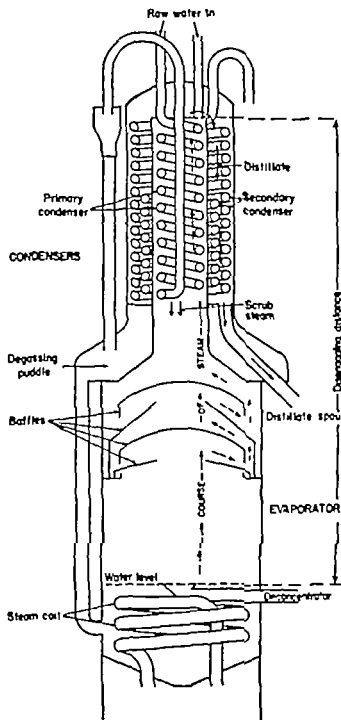


FIGURE 204

Walter

diated use for distilled water so that bacteria cannot grow in residual water and pollute subsequent collections.

Pure water is a comparatively poor conductor of electricity and its specific resistance is therefore an excellent measure of its purity. The efficiency of a still can be

checked quickly and accurately by determining the specific resistance of the distillate by means of a 1000-cycle Wheatstone bridge. The distillate from a well designed, properly operated still has a specific resistance of at least 500,000 ohms and therefore a maximum specific conductance (the reciprocal of specific resistance) of 2×10^{-6} mhos at 20°C. One part of chloride ion per million parts of water reduces the specific resistance from 500,000 ohms to less than 300,000 ohms. The presence of electrolytes in freshly distilled water indicates contamination with tap water by entrainment or leakage from a faulty condenser. It may then be assumed that the distillate has also been contaminated by pyrogenic substances accompanying the electrolytes. Improperly installed stills produce impure water sporadically so a continuous check on the purity of the distillate is necessary to avoid trouble.

Biological methods must be employed to identify actual pyrogen content qualitatively. The simplest test is that of injecting 10 cc of the questionable solution into the ear vein of a rabbit and determining the rectal temperature hourly for three or four hours. The rabbit's normal temperature ranges from 38.3° to 39.8°C under standardized conditions. The febrile reaction which results from the injection of pyrogen raises this to 40.5° to 41.6°C. The technic described in the United States Pharmacopoeia XII, page 606, follows:

PYROGEN TEST

Test Animal

Use healthy rabbits weighing 1000 gm. or more which have been maintained for at least one week on a uniform diet and have not lost weight. Test the thermometer to determine the time required to reach maximum temperature. If the animals have not been previously used for such tests, take four rectal temperature readings on each of the animals at two-hour

intervals one to three days before use. Insert the thermometer beyond the internal sphincter and allow it to remain a sufficient time to reach maximum temperature, but in no case less than ninety seconds, before the reading is recorded. Discard those animals with a temperature in excess of 39.8°C. On the day of the test take a control temperature reading before the injection of the test material. Animals may be used for the test in subsequent tests after a period of not less than two days, provided the control temperature reading taken on the day of the test does not exceed 39.8°C. The reading taken on the test day constitutes the normal temperature of the test animal from which a subsequent rise due to the injection of the test material is calculated. Keep test animals in individual cages protected from disturbances likely to cause excitement. Exercise particular care to avoid exciting the animals on the day of taking the control temperatures and on the test day. Withhold food from any animals used, beginning one hour before the first temperature reading, and permit no food until the day's record is completed. Free access to water is allowed. Keep the animals at uniform temperatures ($\pm 5^\circ\text{C}$) during the control and test period. They should preferably be housed in quarters maintained at constant temperature and humidity.

Conduct of the Test

Warm the product to be tested to approximately 37°C and inject 10 cc per kg of rabbit, intravenously through the marginal ear vein within fifteen minutes subsequent to the control temperature reading on the day of the test. Record the temperature one hour subsequent to the injection and each hour thereafter until three recordings have been made. Syringes and needles used for these injections must have been treated to render them pyrogen-free and then sterilized. Not less than five rabbits shall be used for each test and the test shall be considered positive if three or more of the five animals show an individual rise in temperature of 0.6°C or more above the normal established for each of these animals. If only one or two

of the five animals show a positive response the test must be repeated on a second group of five additional animals. The test shall be considered positive if two of the second group of five animals show an individual rise in temperature of 0.6 C or more above the normal established for these animals.

GLASSWARE

Pyrax glassware is the most satisfactory because of its high resistance to mechanical and thermal shock and its stable annealed surface which resists hydrolysis. The alkaline film formed at the glass-liquid interface of a soft glass flask may cause polymerization of dextrose during sterilization.

Cleaning Glassware

To be chemically clean, glassware must be freed of the initial soil as well as of insoluble deposits resulting from the interaction of washing agents (soaps and detergents) and water or soil containing more than traces of alkaline earths (calcium and manganese). The white, foggy, opalescent film which becomes noticeable as glassware dries is due to insoluble alkali earth soaps formed by this interaction. Dried blood and closely adherent bacterial growths are the usual types of soil encountered. Blood and residual solutions invite and support bacterial life and may be the cause of pollution with pyrogen. Dried fungi are particularly difficult to remove. They may be invisible until hydrolyzed during sterilization, when they swell and become opaque and are mistaken for wisps of cotton floating in the solution. Because glassware is frequently used in the laboratory or utility room, residues of feces, urine, pus, and transudates are often encountered. The most tenacious soil is a greasy film which accumulates when the glassware is used repeatedly without adequate cleaning. A jet of hot detergent solution under sufficient pressure to scour the

inner surface of the flask clean is the most rapid and satisfactory method of preparing containers. Mechanical washers, figure 205, 1, using this principle, are obtainable.

Where mechanical means for cleaning are not available, detergent solutions alone must be relied upon.* They are quite satisfactory in hospitals where the glassware is returned promptly and cleansed daily so that adherent soil is avoided. Under no circumstances should soap and water be used because they foster the precipitation of cloudy films of alkali earth soaps on the inside of the glassware which are difficult to remove. Harsh alkalis must also be avoided because they destroy the annealed surface. Brushes both mechanical and manual, are dangerous because they are likely to scratch the annealed surface, permitting chemical attack or causing fracture during sterilization or after the vacuum has formed.

After glassware has been thoroughly cleansed, it must be rinsed with freshly distilled water, figure 205, 2, to remove any pyrogen contaminating its inner surface. It is then inverted to drain as well as to protect the inside from dust, figure 205, 3. When distilled water is poured from a clean flask, a film of water is left spread on the inner surface. This film breaks immediately and forms droplets wherever greasy soil alters the surface. Clean glass should show no "water breaks" in the film of distilled water left after the final rinsing and should be crystal clear when dry.

Filters

Fritted glass† or porcelain filters‡ are readily cleansed by immersion in a hot solution (60 C) containing 0.5% each of sodium

* Calgon, Calgon, or Harcon.
† Macalaster Filter Company 24 Bond Street
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‡ Sals Company F G 41-10

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Filters

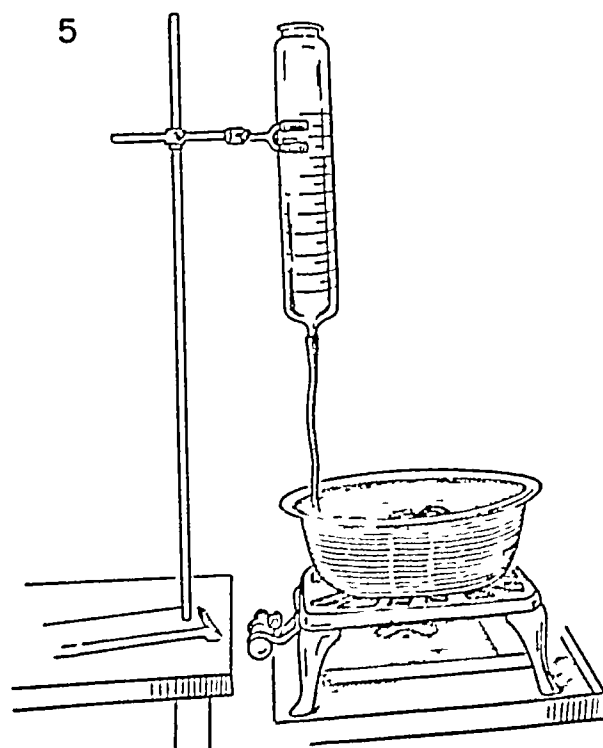
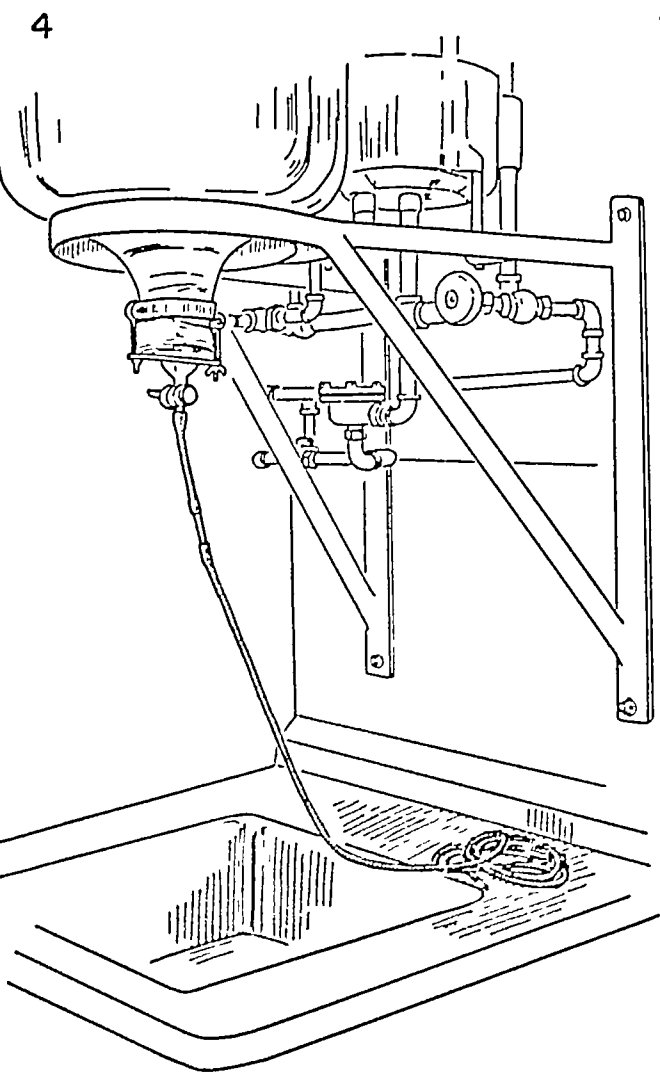
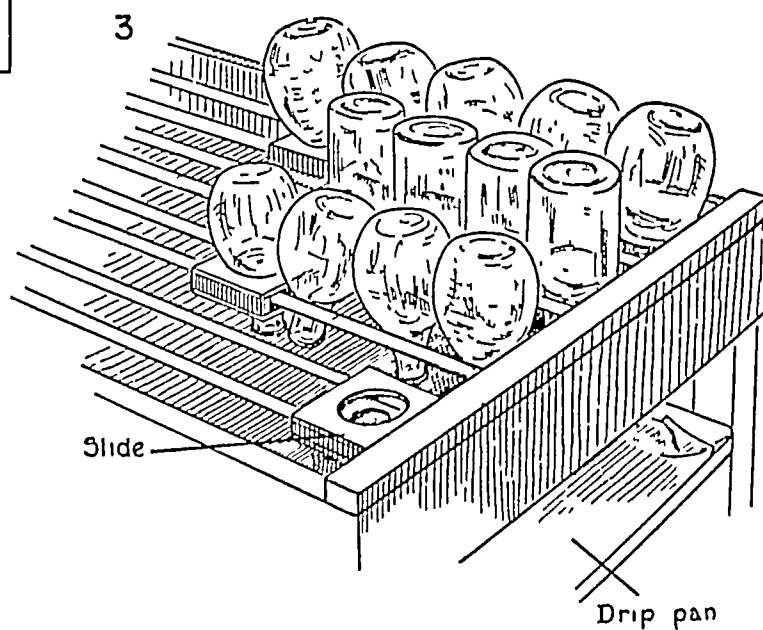
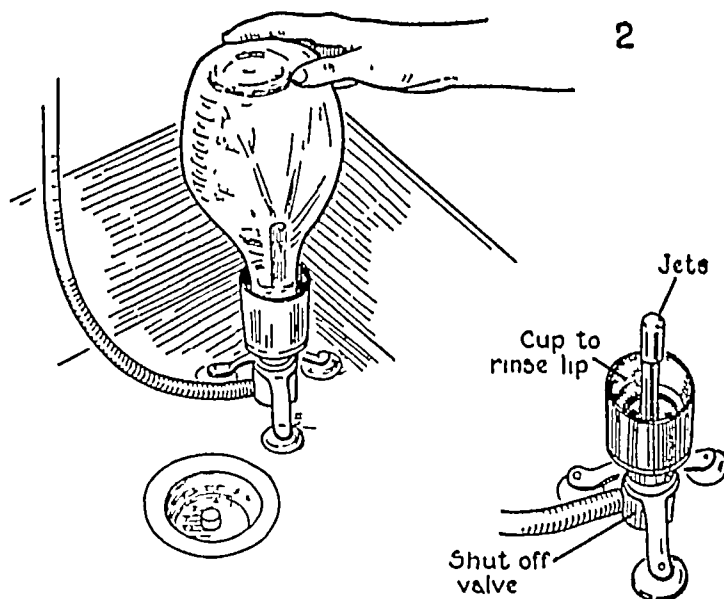
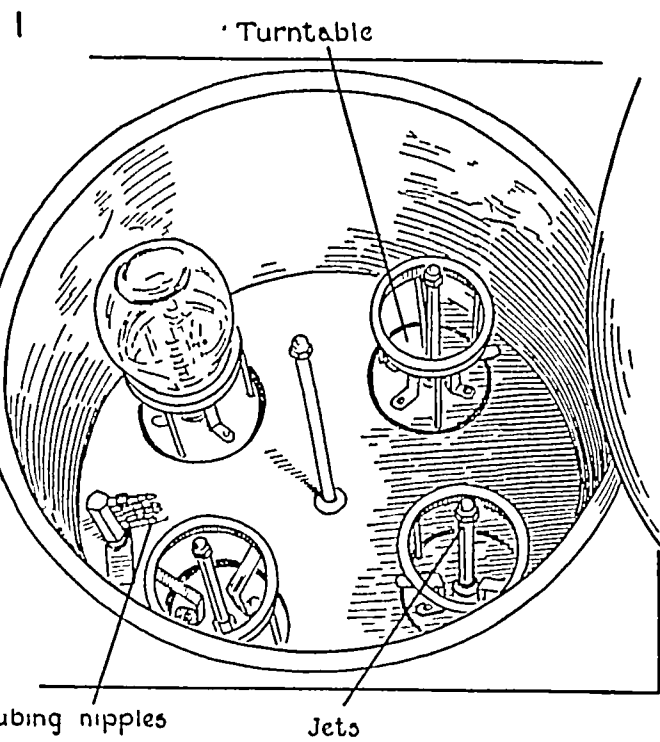
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Calgonite, Calgonac, or Naemool.

† Macalaster-Bicknell Company, 9046 mod. Cambridge Mass.

‡ Selas Company F G -450-10

CLEANING GLASSWARE AND TUBING



nitrite and sodium chlorate in concentrated sulfuric acid. The acid is rinsed from the porous disk by running distilled water through the filter in the reverse direction until the rinsings are neutral to litmus paper or until the conductivity of the rinsings approaches that of the original distilled water

EQUIPMENT

The equipment chosen for parenteral fluids should provide for easy sterilization, safe storage under hermetic seal, and ready administration from the original container. Such apparatus consists of a container which can be sealed hermetically by means of a rubber bushing and stainless steel stopper. The elements of the seal are assembled prior to sterilization so that possible contamination during sealing is avoided. The contents of the flask can be infused by removing and substituting for the stainless steel stopper a special "vent tube." The fluid leaves the inverted container by gravity

Container

The graduated container is mold blown¹¹ of thick Pyrex glass in a shape designed to withstand the water hammer which results when fluids under high vacuum are jarred. Its wide mouth and short neck facilitate cleansing. The contour of the mouth and lip is such that the rubber bushing is held securely in place, figure 206, 1.

The rubber bushing is molded of non-toxic, heat resistant rubber which retains its resiliency after repeated sterilization and does not become tacky and stick to either the container or the stopper. It is shaped to cling firmly to the mouth of the container. The frustum of the bushing fits snugly against the inwardly tapering portion of the

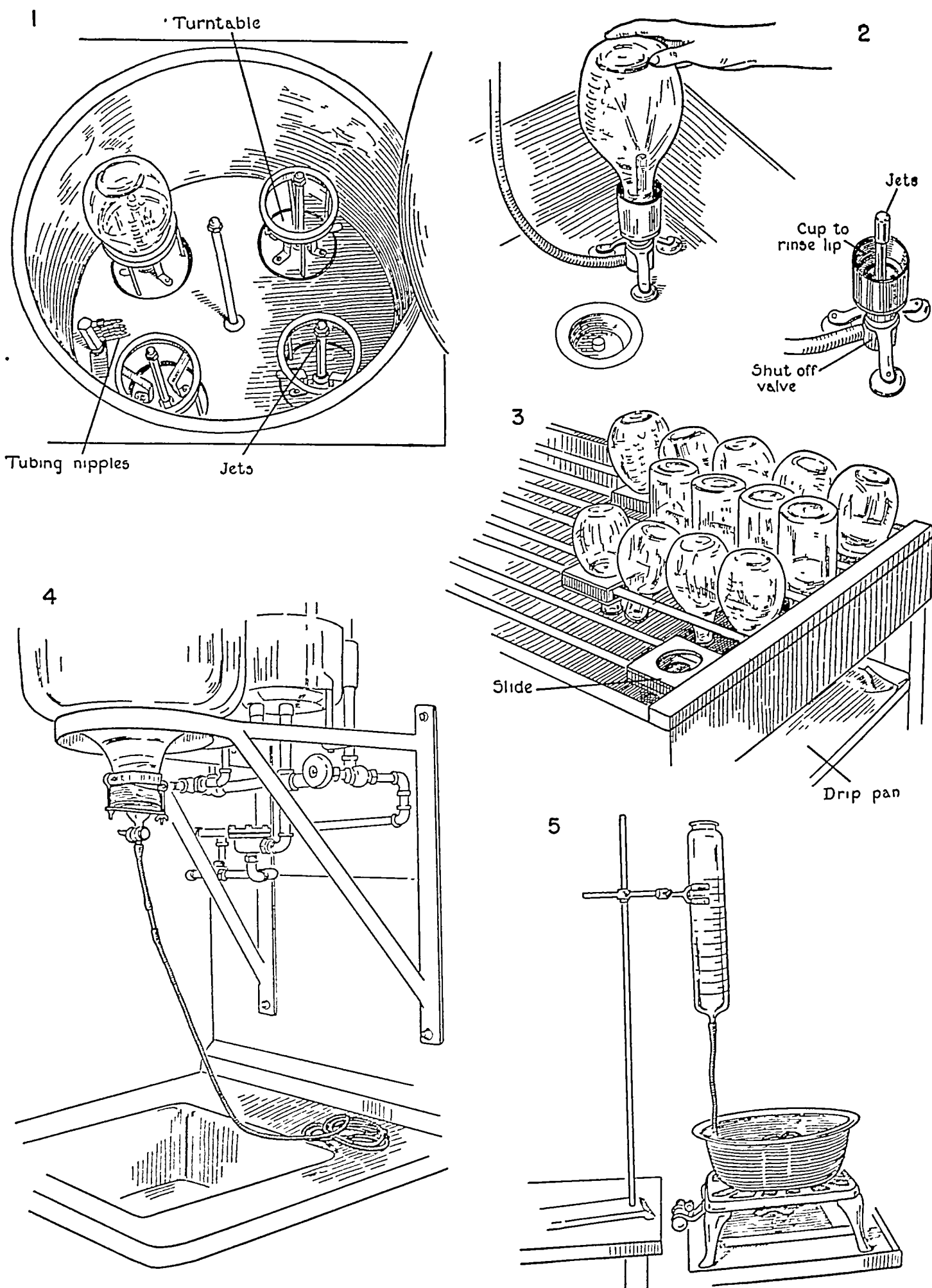
neck of the container to prevent the bushing from being pushed inward during sealing or from being drawn into the flask as the vacuum is formed. The elastic periphery of the skirt clings to the lip of the flask, holding the bushing in position when the stopper is withdrawn or when the container is inverted in the dispensing position.

The stopper is fabricated of a corrosion resistant, passivated stainless steel to withstand the attack of saline solutions, as well as to resist tarnish from an atmosphere of steam or air. The mushroom-shaped stopper is essentially a rugged cap which covers and protects the rubber bushing and a stem which actually provides the closure, figure 206, 2. A longitudinal channel cut into the lower third of the stem serves as an adequate vent for the escape of air and steam during sterilization, figure 206, 1. A rush of steam through this channel, due to the sudden ebullition of vapor following faulty venting of a sterilizer, serves to warn the alert operator that the solutions have been spoiled. On removal from the sterilizer, the stopper is rocked into the bushing so that the solid portion of the stem forms a hermetic seal with the bushing. Precipitation of the water vapor and contraction of the fluid during cooling produces a high degree of vacuum (at least 20 mm. Hg) which aids in maintaining the seal. The water hammer click which is obtained by jarring a sealed flask gives evidence that the container has been properly sterilized and sealed.

The fluid is dispensed from the original container by substituting the hard glass vent tube for the steel stopper, figure 206, 3. This tube comprises a pair of concentric glass tubes, the external diameter of which corresponds to the aperture in the bushing so that it makes a watertight fit with the latter. Two circumferential ribs or beads serve to position the tube firmly in relation to the bushing. Fluid enters the annulus of

¹¹ WALTER, C. W. Simplified Apparatus for the Administration of Parenteral Fluid, *J.A.M.A.*, 106:1982-1983, 1936.

CLEANING GLASSWARE AND TUBING



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¹¹ WALTER, C. W. Simplified Apparatus for the Administration of Parenteral Fluid. *J.A.M.A.*, 106:1982-1983, 1936.

APPARATUS FOR PARENTERAL FLUID

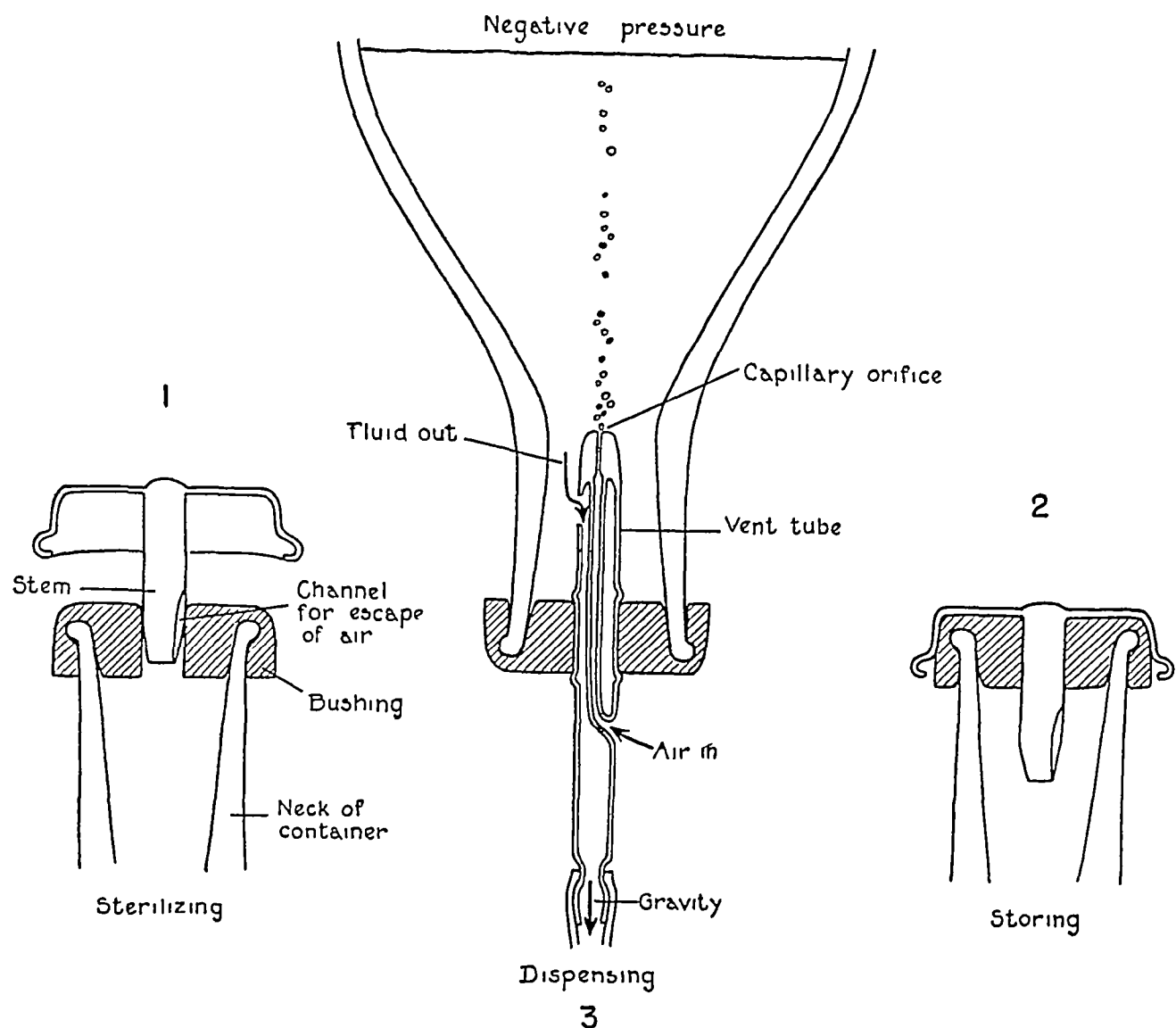


FIGURE 206

Walter¹³

the vent tube through a small orifice just above the inner bead and leaves through the tubing nipple at the outer end of the vent tube, permitting free gravity flow from the inverted flask. Air is metered into the flask to overcome the increasing negative pressure caused by the escape of fluid. This is done by means of the inner tube which communicates with the atmosphere just below the outer bead and leads inwardly to a capillary orifice at the upper end of the vent tube. This capillary is small enough to prevent the fluid leaking through the air

vent when the negative pressure is too low to support the static head of the fluid in the flask.

Rubber Tubing

Rubber tubing suitable for use in parenteral therapy must have a smooth inner surface free from pits, wrinkles, and mold marks, figure 207, 1, where blood and bacterial residues may lodge and make cleansing difficult. The surface of rubber exposed to the fluid can be decreased markedly by selecting a tubing of small inside diameter

(3 mm) A small lumen also facilitates the expulsion of air from the system, since fluid runs through it as a solid column rather than trickling down one side. Any nontoxic rubber can be used, but a rubber compounded to insure maximum heat resistance is more economical. Commercially available tubing* will withstand 75 sterilizations before losing its elasticity or becoming tacky.

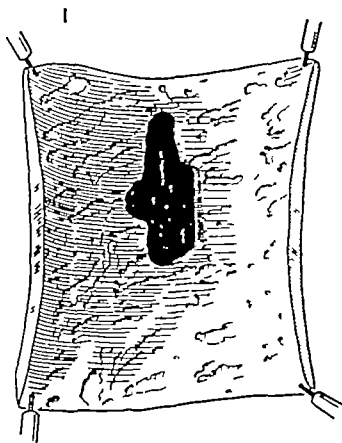
PREPARATION OF INTRAVENOUS KITS

The establishment of a source of chemically pure parenteral fluids is futile unless an equally safe supply of apparatus for its administration is constantly available. Bacterial growth in residual solution or blood in such equipment produces pyrogens which must be removed by adequate cleansing with pyrogen free water. Chemical cleanliness of the inner wall of the vent tubes, rubber tubing, observation tubes, and needles is essential for safe reactionless infusions. Blood clot in the hub of a needle, figure 207, 2, is frequently overlooked.

The cleansing of such apparatus must be done immediately prior to sterilization because bacteria are likely to grow in the moisture purposely left in the apparatus to insure sterilization.

The rubber tubing is cleansed by slipping one end over the nipple of the automatic washer, figure 205, 1, and flushing the lumen for one minute with detergent solution under pressure. Freshly distilled water is then trickled through the tubing, figure 205, 4, for ten minutes after the discharge tests neutral to litmus paper to remove the detergent and leave the inner surface chemically clean. No attempt is made to dry the lumen of the tubing. An alternate technique requires no special equipment. The tubing is coupled with glass connectors and boiled

SOURCES OF PYROGEN



2

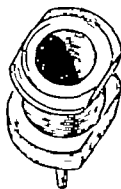


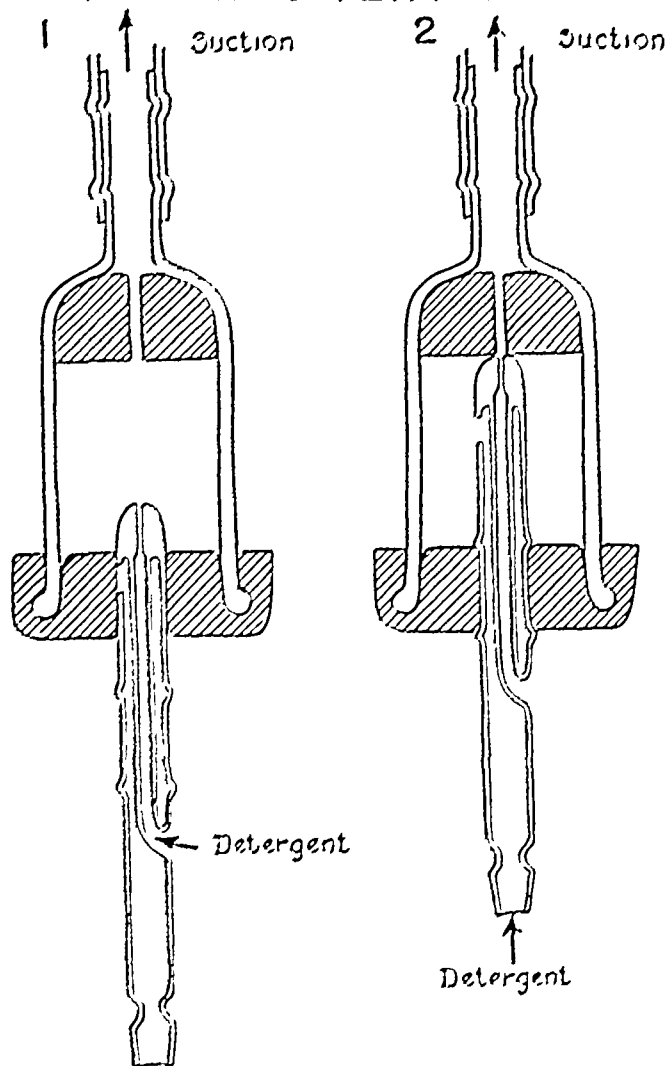
FIGURE 207

11 after 12

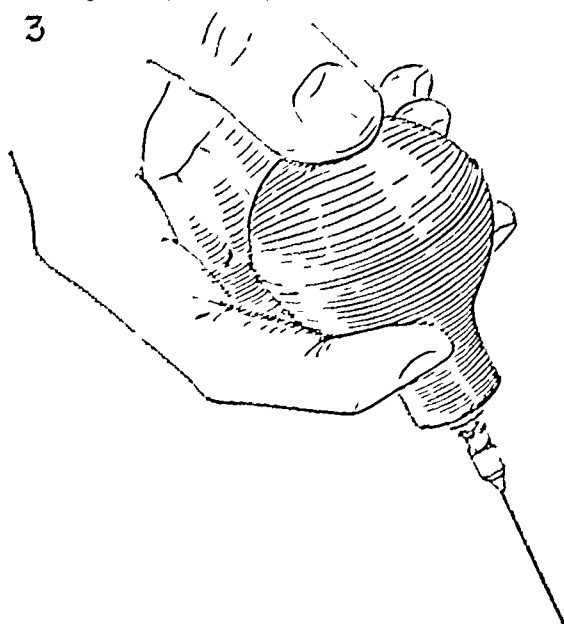
for fifteen minutes while submerged in a 0.5% solution of sodium hydroxide, or 0.07% Haemosol care being taken not to insert the connectors as far as the original adaptor was inserted lest the glass protect dirt. Alkali solution from a convenient reservoir is run through the tubing continually during the boiling figure 205, 5. After the

Macalaster Bucknell Company Fenwal Brand.

CLEANING VENT TUBE



CLEANING NEEDLE



tubing is cool, distilled water is run through it as described.

Needles are cleansed by reaming them with a snugly fitting stilette* and forcing hot detergent solution through the cannula, figure 208, 3 They are rinsed with distilled water and inspected critically, figure 113, not only for cleanliness and sharpness but also for weakness which might cause unexpected breakage. Needles should not be sterilized with stilettes in place because the electrolytic action set up between the stilette and the needle causes early corrosion and weakening. Needles can be protected against accidental dulling during sterilization by inserting them into an hourglass protector tube and plugging the ends with cotton, figure 113, 12. It is easy to remove the needles from these tubes without danger of contamination, figure 213, 8.

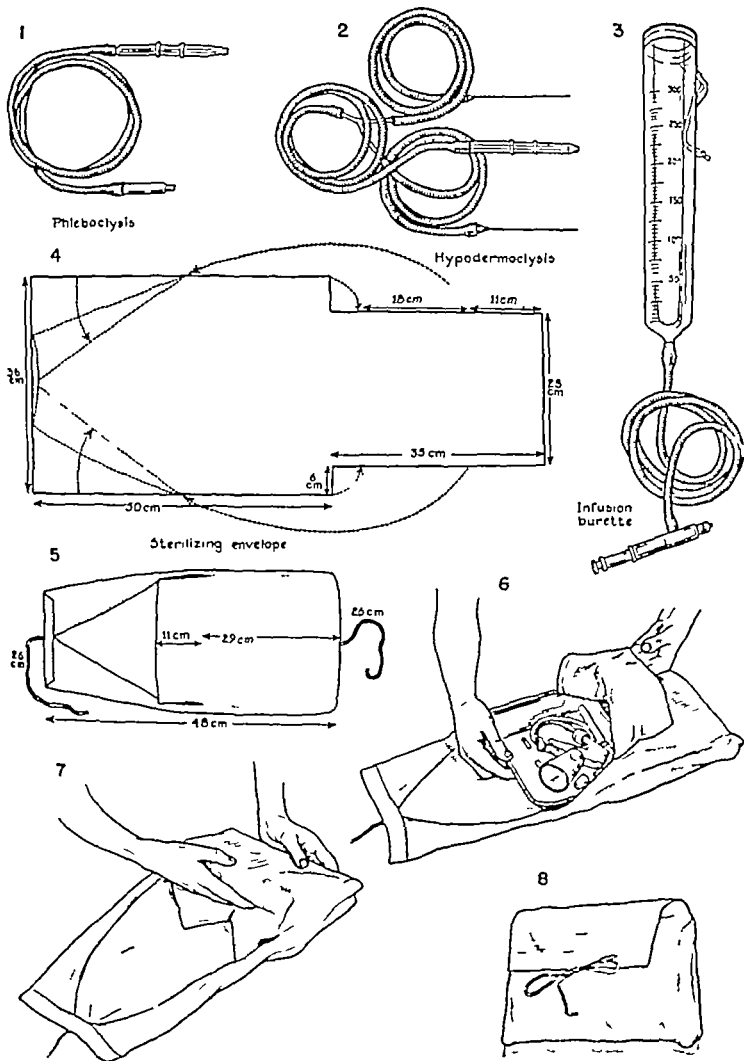
The small glass parts, vent tubes and observation tubes can be cleansed readily by sucking hot detergent solution through them. This can be done most easily in the case of the vent tubes by using a special holder which permits positioning of the tube, so that the capillary vent and the fluid passage can be cleansed and rinsed separately, figure 208, 1, 2.

The infusion apparatus is reassembled, figure 209, 1, 2, 3, without drying, and arranged in a clean aluminum tray. This tray is inserted into the sterilizing envelope, figure 209, 4, 5, 6; the inner flap is tucked beneath the pan, figure 209, 7, and the outer flap is securely tied, figure 209, 8. The residual water inside the rubber tubing is vaporized in the sterilizer and provides the moisture essential for sterilization. It is important to have the tubing moist because it is difficult to clear sufficient air from a length of dry coiled rubber tubing to attain sterilizing conditions.

FIGURE 208

* Assorted sizes are marketed by needle manufacturers

ASSEMBLING AND PACKAGING INFUSION KIT



STERILIZATION

The kits are packed into a dressing sterilizer so that the bottoms of the aluminum trays are in a vertical position. This permits the steam to displace the air in the tray and results in rapid development of sterilizing temperatures. It is advantageous to sterilize them alone or with loosely wrapped rubber goods because little heat is required to bring the kits to sterilizing temperature. They should be sterilized for thirty minutes at 121°C exhaust line temperature.

After sterilization, the envelopes are dried by leaving the sterilizer door ajar for fifteen minutes while the steam pressure is maintained in the jacket of the sterilizer. If the kits are stored with the trays inverted, there is little danger of contamination from dust and they can be kept until needed.

Expendable Tubing

Plastic tubing, Tygon S-22-1 2.8 mm i.d. \times 0.05 mm. wall thickness, may be used for the infusion of parenteral fluid. The tubing can be used as it comes from the manufacturer without cleaning or treatment of any kind. The lumen is rinsed with freshly distilled water and the infusion set is assembled using vent tubes with small nipples and needles with male hubs. The glass adapter is unnecessary because the tubing is transparent. Just before the tubing is coiled into the aluminum tray, it should be stretched tautly to align the molecules so that the plastic will withstand heat. Sterilization is accomplished by thirty minutes' exposure to saturated steam at 115.5°C. The sets must stand for several days following sterilization to permit the tubing to dehydrate and regain its original elasticity.

CHEMICALS

Although the United States Pharmacopoeia does not specify dextrose suitable for

intravenous use, U.S.P. XII or C.P. anhydrous grades of chemicals are usually satisfactory. The acceptance of a particular lot of chemicals also depends upon the quantity of particulate matter contaminating it. Excessive dust clogs the filters quickly and is evidence of careless handling prior to packaging. Dust, dirt, debris, or dried insect parts indicate contamination of a degree likely to introduce foreign proteins into the chemicals. Dirty chemicals must be rejected or purified by adsorption. Transfer of chemicals must be done with suitable implements. The use of the hands, or dirty scoops, spatulae, or scale pans must be avoided. Chemicals which touch the hands or drop upon the balance or table must be discarded.

Dextrose may contain amino acids and carbohydrate condensation products which, when denatured by the heat of sterilization, appear as white, flocculent precipitates. Various acid dehydration products of dextrose, formed by side reactions during its manufacture, may also be present. These compounds are colorless but on aging degrade to levulinic acid, a brown compound. This conversion occurs rapidly in hot aqueous solutions or on exposure to light and accounts for the yellow color, often mistaken for caramelization, developed during sterilization or storage of some dextrose solutions.

PREPARATION OF SOLUTIONS

Bulk dilution and mass filtration of solutions are too inconvenient for most hospitals. The problems entailed in handling large quantities of fluid can be avoided by a technic which also limits potential spoilage from improper mixing, faulty filtration, careless contamination or uncleanness to individual flasks. Such technic is based upon the filtration of a relatively small proportion of the final solution in the form of a

DIRECTIONS FOR MAKING DIVERS SOLUTIONS

SOLUTION	CHEMICALS IN STOCK SOLUTION	NET WEIGHT OF STOCK SOLUTION GR.	C. GR. ADDED TO FLASK C. GR.	NET W. BOTT OF FLASK GR.
5% dextrose in distilled water	1000 gm. dextrose c. p.	2355	170	1064
10% dextrose in distilled water	1000 gm. dextrose c. p.	2355	270	1085
0.85% saline	170 gm. sodium chloride c. p.	1108	30	1047
5% dextrose in 0.85% saline	(a) 1000 gm. dextrose c. p. (b) 170 gm. sodium chloride c. p.	2355 1108	100 0	1766
10% dextrose in 0.85% saline	(a) 1000 gm. dextrose c. p. (b) 170 gm. sodium chloride c. p.	2355 1108	70 30	1096
Ringer's U.S.P.	9.0 gm. potassium chloride c. p. 10.0 gm. calcium chloride c. p. 258 gm. sodium chloride c. p.	1180	30	1173
50% dextrose	1000 gm. dextrose c. p.	2406	105	
50% sodium	1000 gm. sodium c. p.	2418	105	

Allowance has been made for 5% loss during sterilization.

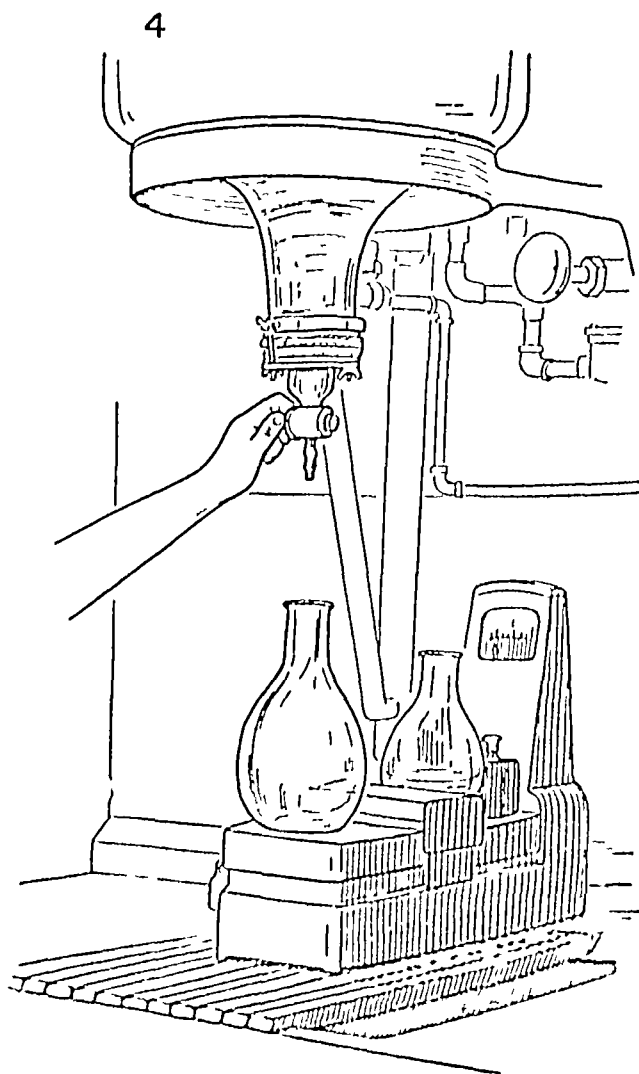
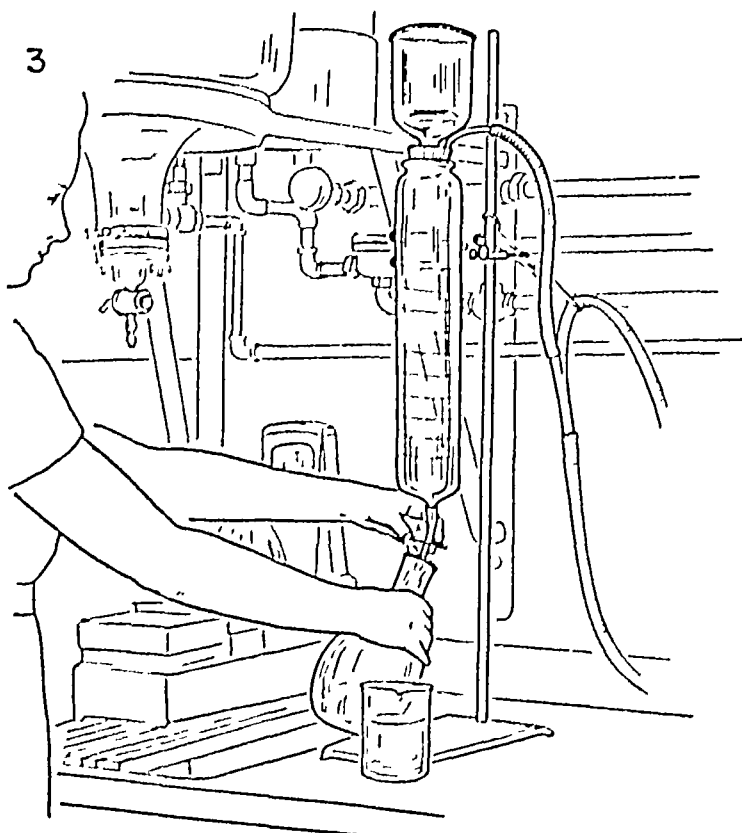
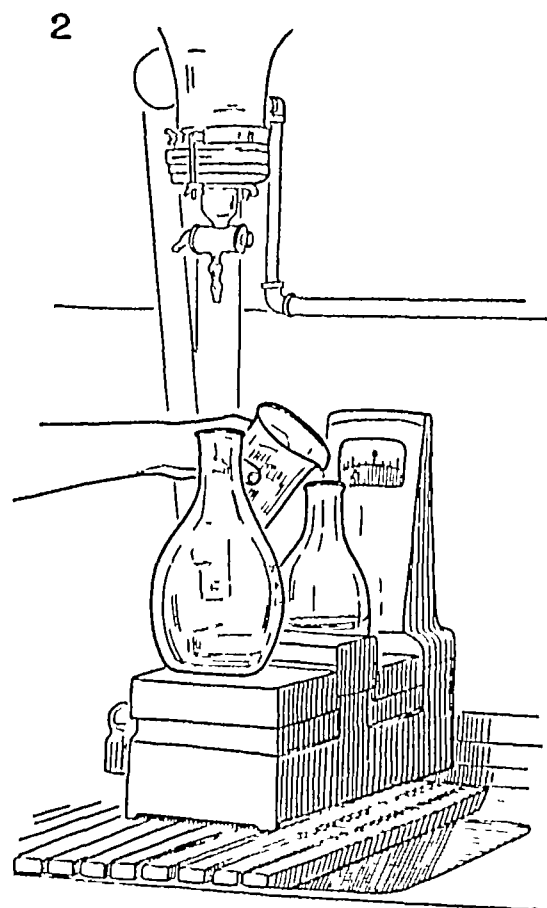
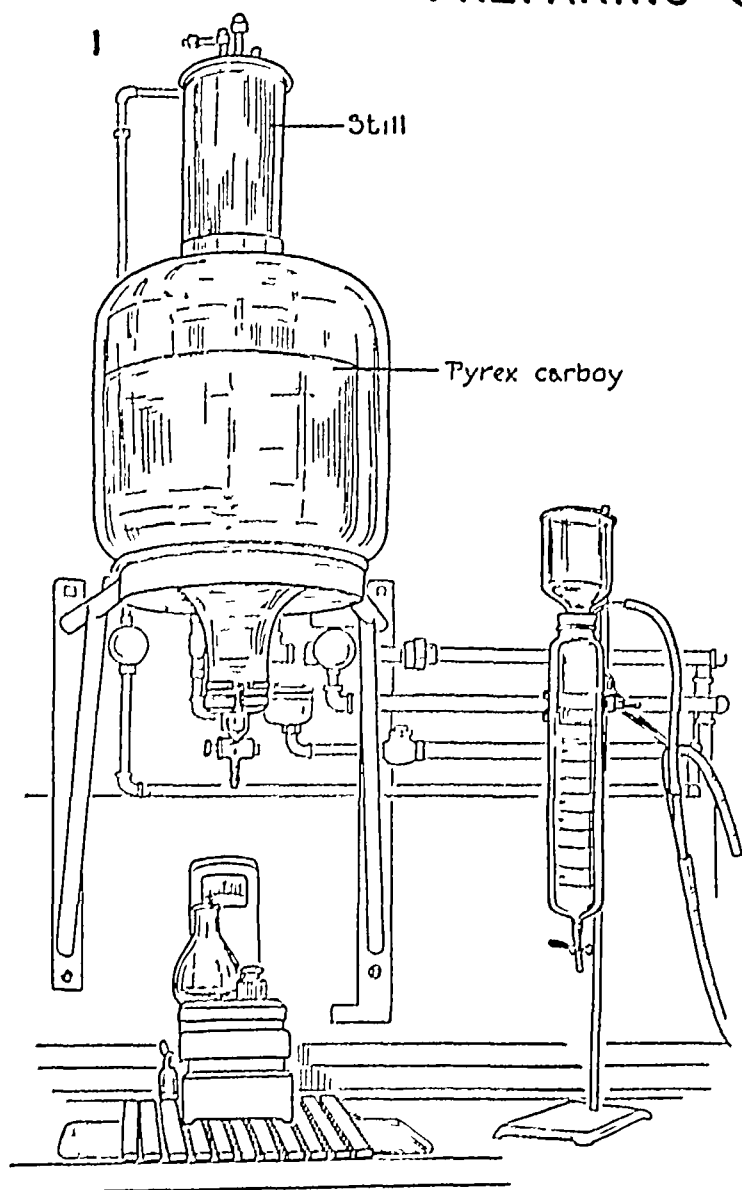
concentrate. This concentrate is then diluted with distilled water which contains no particulate matter when properly distilled and collected. Pyrogens and other contaminating substances can easily be removed by adsorption on activated charcoal¹¹ or filtration through an activated asbestos filter¹⁰. In the average hospital, the concentrate is filtered most advantageously into a large volumetric burette whence a suitable portion is measured into a container and distilled water added until the proper dilution by weight is made. Formulas for divers solutions are listed above.

Five per cent dextrose solution is prepared from a fresh stock solution made by adding hot distilled water to 1000 gm. of chemically pure dextrose (previously weighed out in a counterbalanced flask) until a net weight of 2355 gm. has been reached. The flask is stoppered with a clean rubber stopper and shaken until solution is complete. One part activated charcoal is added for each 250 parts of solution. The flask is shaken again and heated to 100°C. Pyrogens are adsorbed on the charcoal which also decolorizes and clarifies. After the charcoal settles out, the clear supernatant fluid is filtered through fritted glass with the aid of suction directly into a Pyrex burette figure 210, 7. The filtrate should be crystal clear and colorless. One hundred cc. of the filtrate are measured, figure 210, 3, into a previously counterbalanced, figure 210, 2, Pyrex container and distilled water is added to a net weight of 1066 gm., figure 210, 4. A clean rubber bushing is fitted into the mouth of the flask, its skirt is turned down, figure 211, 5, and the channeled stem of the steel stopper is partially inserted into the bushing, figure 211, 6. After sterilization, the stopper is pushed down to complete the seal, figure 211, 7.

STERILIZATION OF SOLUTIONS

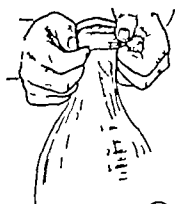
The sterilization of liquids presents a special problem for several reasons. First, heating of the solutions occurs by contact between the cold container and the steam. The size, shape, thickness, and heat conductivity of the container influences the rate at which the solutions are heated to sterilizing temperatures. As was the case with instruments, air clearance from the sterilizer is important because retained air decreases the heating efficiency of the steam markedly, figure 45. Second, the bactericidal action begins as soon as the liquid begins to heat¹² and continues throughout the sterilization.

PREPARING SOLUTIONS

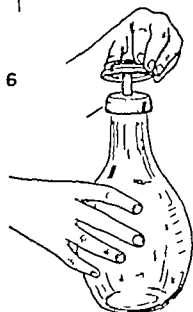


PREPARING SOLUTIONS

5



6



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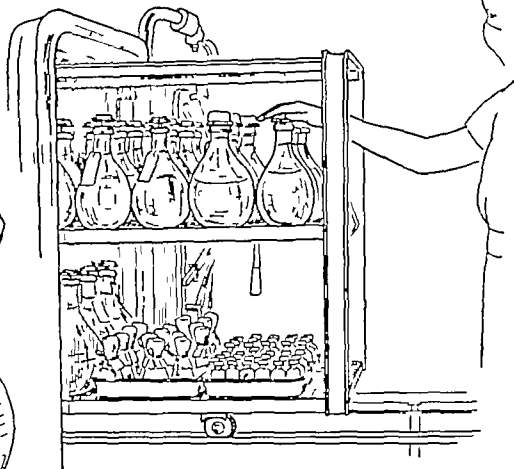


FIGURE 211

lizing cycle until the fluid has cooled again. In this respect, solutions differ markedly from dressings where heating occurs by convection of steam into the bundle and areas not touched by steam are still cold. Penetration, therefore, is not a problem in sterilization of solutions, instead, the total exposure to heat is the factor which must be considered. Third, air is expelled from a container in which there is liquid enough to fill it with steam because the vapor pressure inside the container is determined by the temperature of the liquid and hence, the evaporation of the liquid can be relied upon to form sufficient steam to purge all the air. Enough steam is produced by 2 cc. of water to purge the air from a liter flask, figure 36.

* Ball, C. O. Thermal Process Time for Canned Food, *Bull. Nat'l Res. Council*, Vol. 1, Pt. 1, 1923.

Fourth, after the liquid has been heated to sterilizing levels care must be taken to avoid relieving the steam pressure in the chamber surrounding the flask because the temperature of the liquid is 121°C and a vapor pressure of 1536 mm Hg is necessary to prevent violent ebullition. If the liquid is allowed to cool, the vapor pressure and temperature decrease simultaneously along the vapor pressure curve for water and ebullition is prevented. Fifth, there has been much discussion regarding the desirability of exposing solutions to heat for longer periods than necessary to effect sterilization. Some have believed that small flasks should be exposed for shorter periods than large ones to avoid deterioration or concentration of the solutions. Most solutions which can be sterilized are sufficiently stable so

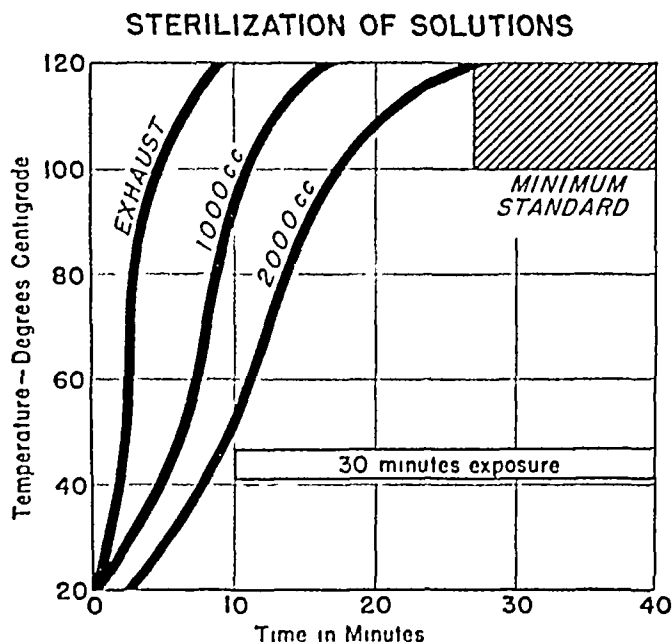


FIGURE 212

that prolonged exposure does no harm and because concentration of the solutions is a direct result of faulty operation of the sterilizer, it can occur just as readily after short sterilizing periods as after longer ones. Care must be taken to adjust the pH to stabilize solutions of chemicals in which that factor determines stability toward heat.

The solutions discussed in this chapter can be sterilized by exposure to saturated steam at 121°C for thirty minutes, realizing full well that the curves for heating various quantities of solution may differ as indicated in figure 212. At the end of the sterilizing cycle, the steam supply to the sterilizer must be shut off and the sterilizer must be permitted to cool to 100°C, 0 gage pressure, before the door is opened.

PHLEBOCLYSIS

When an infusion is ordered, it is necessary to obtain only an intravenous kit and a container of the appropriate solution. The identity of the solution is always checked by reading the label, figure 213, 1. The sterility of the solution is tested by striking the steel stopper sharply, driving

the flask suddenly away from its liquid contents, figure 213, 2. The liquid subsequently strikes the flask again, producing a metallic water-hammer click. This phenomenon indicates the existence of a vacuum of at least 250 mm Hg, assurance that the flask was heated sufficiently to drive off the air prior to sealing and that the hermetic seal has not been broken. The fluid is administered from the original container by removing the steel stopper by a spiral, rocking twist, figure 213, 3. An inrush of air as the channel in the stopper clears the bushing is additional evidence that the flask has not been opened following sterilization.

The outer flap of the sterilizing envelope is loosened and the corners of the envelope are grasped and pushed together to extrude the aluminum tray from the envelope, figure 213, 4. This provides simultaneously a sterile field and a receptacle to catch the liquid when the air is being expelled from the rubber tubing. The vent tube is picked up by grasping the portion of rubber tubing stretched over its end and the tube is partially inserted into the rubber bushing. The container is tipped sufficiently to moisten the hole in the bushing, figure 213, 5, and the vent tube is wiggled into the hole in the rubber bushing, figure 213, 6, until the groove between the shoulders of the vent tube is seated in the rubber bushing, figure 206, 3. To create sufficient negative pressure to prevent leakage through the air vent, the flask is inverted and hung in the splitting bracket so that the solution can run through the rubber tubing into the aluminum pan before the needle is attached, figure 213, 7.

The needle is readily withdrawn from the hourglass sterilizing tube by removing the cotton plug and inserting the ground glass tip of the observation tube into the hub of the needle, figure 213, 8. The needle can be attached firmly enough to prevent

it dropping off or to avoid contamination

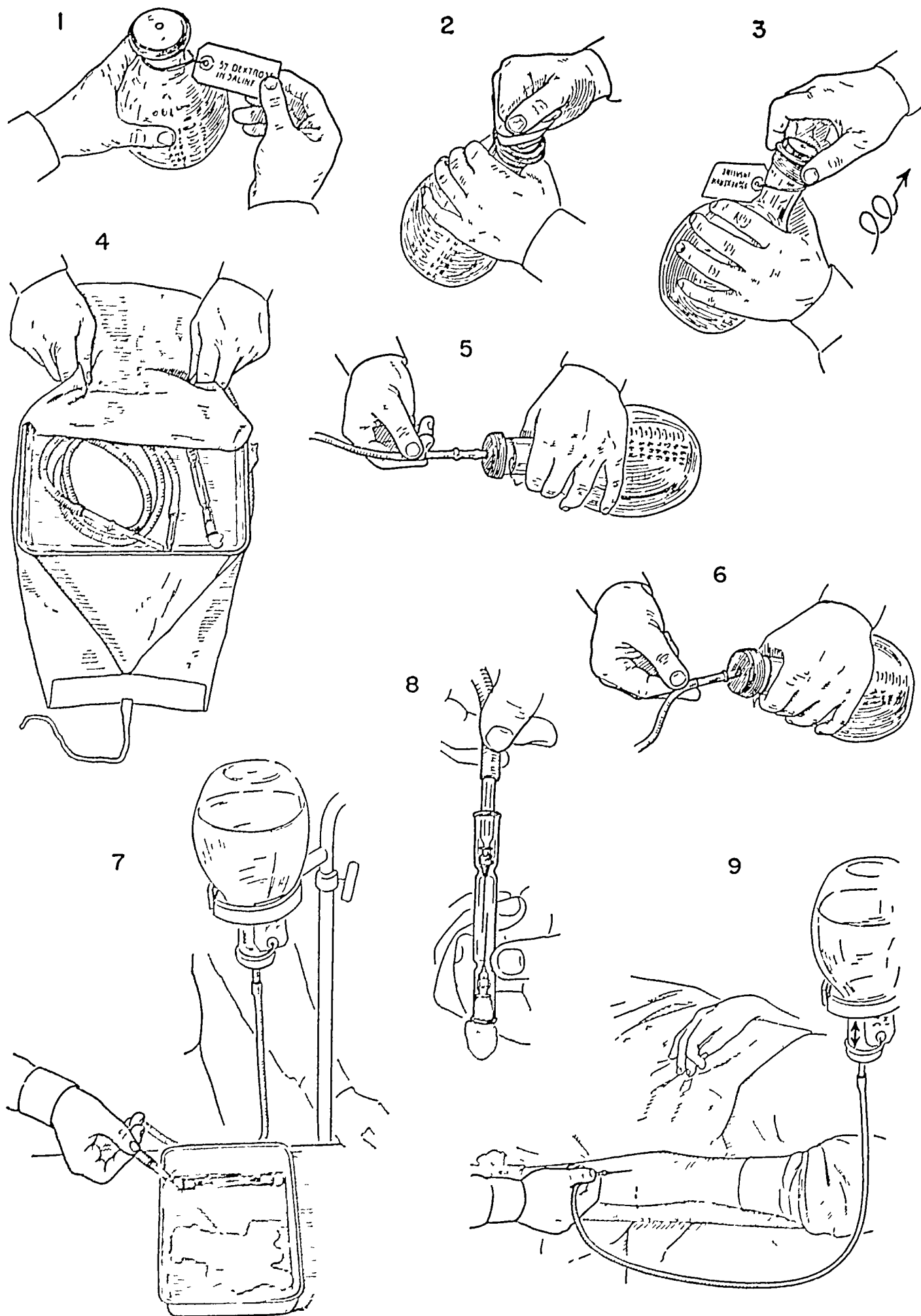
The rate of injection is predetermined within limits by holding the needle level with the vein into which it is to be inserted and varying the pressure head by raising or lowering the flask, figure 213, 9 For all practical purposes, either a 19- or 21-gage needle will provide an ample range of flow. When infusions are to be given slowly, 24- or 26-gage needles permit more accurate control. Because the stream is moving rapidly through the cannula, blood does not clot in fine-bore needles. If a tubing clamp is used to regulate the flow, it must be applied as near the needle as possible to prevent the development of negative pressure within the tubing. Death from air embolism has been observed during infusion where air was sucked into the tubing through perforations or cracks. The infusion is now ready to start.

Because venipuncture is the critical part of a phlebotomy, a description of a standard technic is included. Many times the infusion apparatus is blamed when lack of skill is the real cause of failure. Blaming apparatus is a poor excuse because every piece of equipment should be thoroughly tested before it is used on a patient. If the steps outlined in the preceding paragraph are performed routinely, faulty apparatus plays an insignificant role in failure. An often forgotten act of mercy is to be certain that the patient has an empty bladder when parenteral therapy is begun. A distended bladder causes restlessness, and clumsy attempts to use the bedpan often disturb the intravenous needle. Adequate splinting of the arm is also essential. A splint board long enough to extend from the tips of the fingers to beneath the shoulder of the patient is desirable, figure 214, 10. Shorter ones are useless and those which are applied so that the hand dangles helplessly over the end are a torment to the patient. The rubber tube

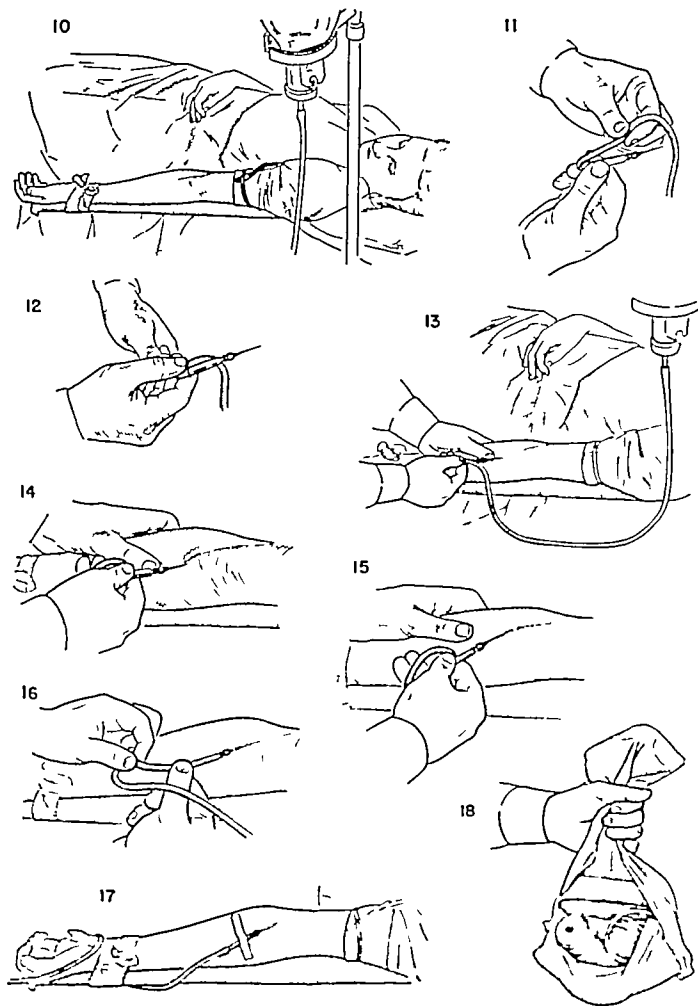
which is to be used for a tourniquet should be placed between the arm and the splint board before the latter is lashed to the patient's wrist.

The skin overlying the antecubital fossa is then disinfected and a vein is selected, either because it is prominent or because its course can be palpated accurately beneath the skin. The rubber tubing is folded on the observation tube, figure 214, 11, and the tubing is squeezed against the glass between the thumb and forefinger of the right hand, care being taken that the bevel of the needle is uppermost, figure 214, 12. The skin of the arm is tensed with the left thumb to fix the vein firmly in position, figure 214, 13. The tip of the needle is thrust through the skin at a point 1 cm. lateral to the vein, figure 214, 14. The skin and subcutaneous tissues are then lifted by the tip of the needle until the latter overlies the vein, figure 214, 15. The needle is then pushed into the wall of the vein with a slow steady thrust. At this point, care must be taken not to release tension on the skin with the left thumb or the vein is likely to slip away. A sudden lack of resistance is readily appreciated as the tip of the needle enters the lumen and the cannula is inserted as far into the vein as it will go, figure 214, 16. The cannula of the needle is thrust all the way into the vein so that its length prevents angulation of the needle and penetration of the opposite wall. Before the needle is released, it is given a one-quarter turn so that the beveled end of the needle which was introduced uppermost will face the lumen of the vein when the skin, which has been lifted medially over the vein, is released. The rubber tubing is then pinched between the thumb and forefinger of the left hand, the observation tube is steadied and the rubber tubing is stretched somewhat to create negative pressure within its lumen, figure 214, 16. Blood can be as-

PREPARING APPARATUS FOR INFUSION



VENIPUNCTURE



pirated into the observation tube to assure the operator that a successful venipuncture has been made. The observation tubing is firmly attached to the patient's skin with a small strip of adhesive tape, figure 214, 17. As an additional safeguard, the rubber tubing should be given a single turn about the wrist. It seems superfluous to remark that the tourniquet must be removed before the infusion will flow, nevertheless, this point is often forgotten.

More fluid than is contained in one flask may be given by substituting a second flask as the first one is emptied. This is done by clamping off the rubber tube with a Hoffman clamp before removing the vent tube from the first flask. The vent tube is then inserted into the bushing of a fresh flask of solution, the container inverted and the Hoffman clamp removed.

After the infusion has been completed, a small gauze sponge is held gently over the skin puncture and the needle is withdrawn. The patient presses on the sponge with the elbow extended for at least five minutes until the hole in the vein has sealed off. This precaution prevents extravasation of blood into the subcutaneous tissues with the subsequent unsightly discoloration of the overlying skin.

HYPODERMOCLYSIS

Two liters of isotonic solution may be introduced into the loose areolar subcutaneous tissues during the course of several hours. There is little to be gained in forcing the fluid into the tissues more rapidly than it is absorbed. The fluid is most conveniently infused into the loose areolar tissue along the antero-lateral aspects of the thighs. It may also be injected into the areolar tissue overlying the gluteal fold, that of the flanks or beneath the pectoral muscles. The apparatus, figure 209, 2 for the infusion is prepared by inserting the vent tube into the rubber

bushing as described on page 292. The flask is inverted and the air is expelled from the tube. The skin just above the knee on the lateral aspect of the thigh is disinfected and a fold of it is pinched up between the thumb and forefinger, figure 215, 1. The sharp needle is thrust quickly into the areolar tissue, figure 215, 2, which lies between the subcutaneous tissues and the fascia overlying the quadriceps muscles. The needle is thrust into this tissue until the hub strikes the skin. A strip of adhesive tape is then applied to anchor the hub to the skin, figure 215, 3. If the needle has been inserted properly, a symmetrical mound appears over the tip of the needle. If the needle is too superficial, a wheal of fluid forms in the skin which then takes on the typical appearance of orange skin. If the infusion is painful or runs slowly, the needle has probably been inserted through the fascia into the muscle. This fault must be corrected to avoid lameness when the patient begins to walk. Nursing care can do much to facilitate absorption of the fluid and prevent discomfort. Too rapid or too great distention of the tissues is extremely painful and retards absorption. The rate of flow must be regulated by raising or lowering the flask.

RETURN OF APPARATUS TO THE CENTRAL SUPPLY ROOM

The container is removed from the splitting bracket. The vent tube is removed from the bushing and the tubing assembly and flask are put into the aluminum pan along with the stainless steel stopper, extra needles, and the hourglass sterilizing tube. The bushing is left in place in the flask to protect the lip against chipping, figure 214, 18. The pan is then inserted longitudinally into the sterilizing envelope and returned to the central supply room. The long flap of the envelope serves as a handle so that five or six sets can be carried

HYPODERMOCLYSIS

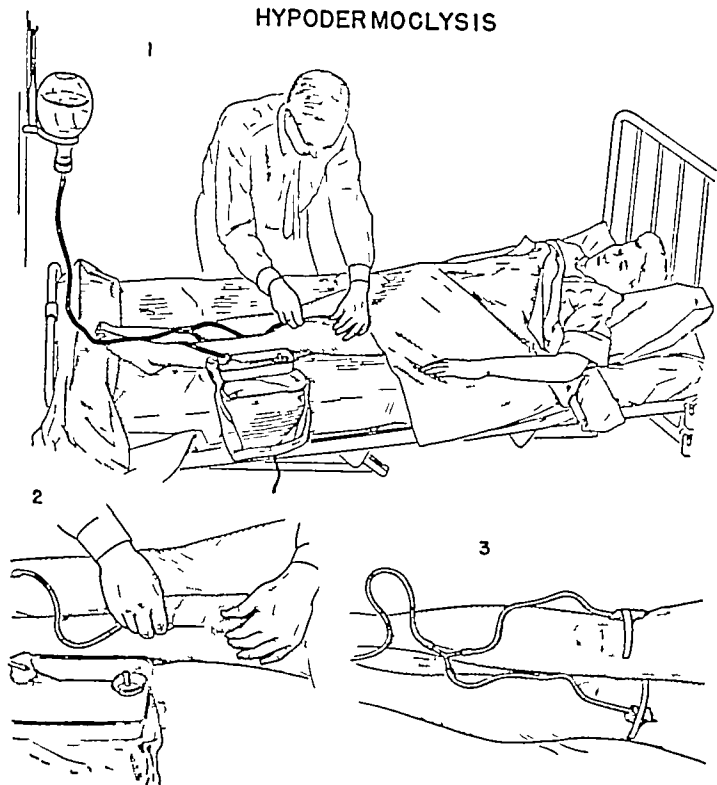


FIGURE 215

conveniently in one hand without danger of loss or breakage

Fluids for use at the operating table are conveniently made up and sterilized in two liter flasks similar to those described on page 283. These flasks can be covered with a paper flaskhood secured by a string or rubber band, figure 156, 3. In use, the string or rubber band is removed, the skirt of the flaskhood is flared out and it is grasped at the top and carefully taken off the neck of the flask. This can be done readily without contaminating either the outside of the flask or the inside of the hood, figure 144, 1. The solution is then poured directly from the flask without discarding the first few drops as is customary with other types of closures. The flaskhood is carefully replaced and the remaining fluid can be used again. Flaskhoods have several disadvantages. The flasks must be handled carefully to avoid drenching the hoods. Flasks protected by hoods are contaminated with air-borne bacteria following eight to ten days' exposure to atmospheric conditions. Shifts in temperature or barometric pressure cause the flasks to breathe sufficiently to carry bacteria into them. The contents of flasks which have been covered with hoods should not be considered sterile after five days and should be discarded routinely after that time.

A more satisfactory closure is that illustrated in figure 216. A heat resistant rubber collar, figure 216, 1, designed to hug the neck and lip of the flask is used to effect the closure between the glass and a molded phenolic cap. The collar is provided with a bead, figure 216, 2, which makes a tight seal with the inside of the cap so that the portion of the collar distal to it is sealed against contamination, figure 216, 4. The flaring upper lip of the collar, figure 216, 2, 5, facilitates pouring solutions directly from the flask without danger of contamination

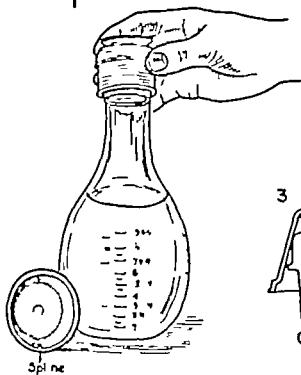
by contact with parts of the collar which have not been sterilized and sealed against contamination.

The phenolic cap is a simple cup with a smooth inner surface except for a spline extending from the lip inward for a distance of 1 cm, figure 216, 2. The spline underlies an arrow which has been molded in the outer edge of the cap to indicate the position of the groove, figure 216, 6. When the cap is forced down on the collar, the bead about the collar and the flaring lip seal tightly against the cap, forming a double vacuum seal, figure 216, 4. To remove the cap, the vacuum in the annular space between the bead and the lip must be relieved first, otherwise, few people are strong enough to remove the cap. This is done by lifting the side of the cap indicated by the arrow until the spline passes the bead, figure 216, 3, breaking the vacuum in the annular space. The cap is then lifted further to break its seal with the flaring lip. The design of the pouring lip is such that the cap can be pushed downward on the collar to reseal the flask, figure 216, 6. The solutions are prepared as described on page 288. The rubber collar is fitted to the flask and the phenolic cap is placed lightly on top of the collar, figure 216, 7. The solutions are sterilized for thirty minutes at 121°C and after the sterilizer has cooled to 100°C the flasks are removed and the cap is pressed downward firmly to effect a hermetic seal, figure 216, 8. When the flask cools, some of the water vapor condenses and a vacuum is created which maintains the seal indefinitely.

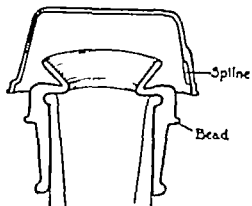
Small quantities of solution — 50% dextrose, distilled water for sterile diluent, saline, etc — are conveniently sterilized in 125 cc Erlenmeyer flasks and sealed with a diaphragm stopper, figure 217, 1. The stopper, with its skirt turned up, is lightly inserted in the mouth of the flask, fig-

APPARATUS FOR STERILE FLUID

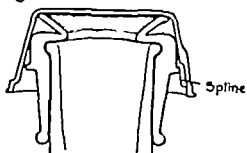
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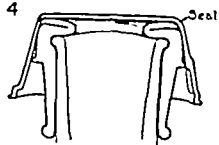
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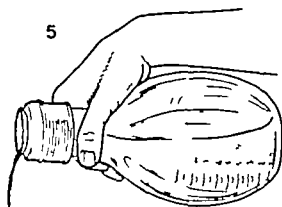
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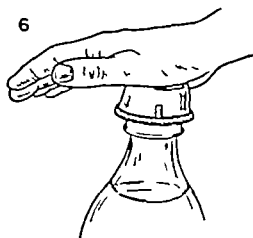
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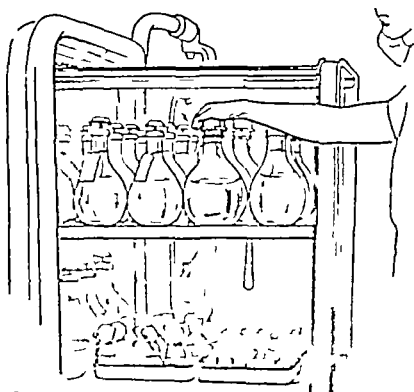
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7



STERILIZING SMALL QUANTITIES OF FLUID

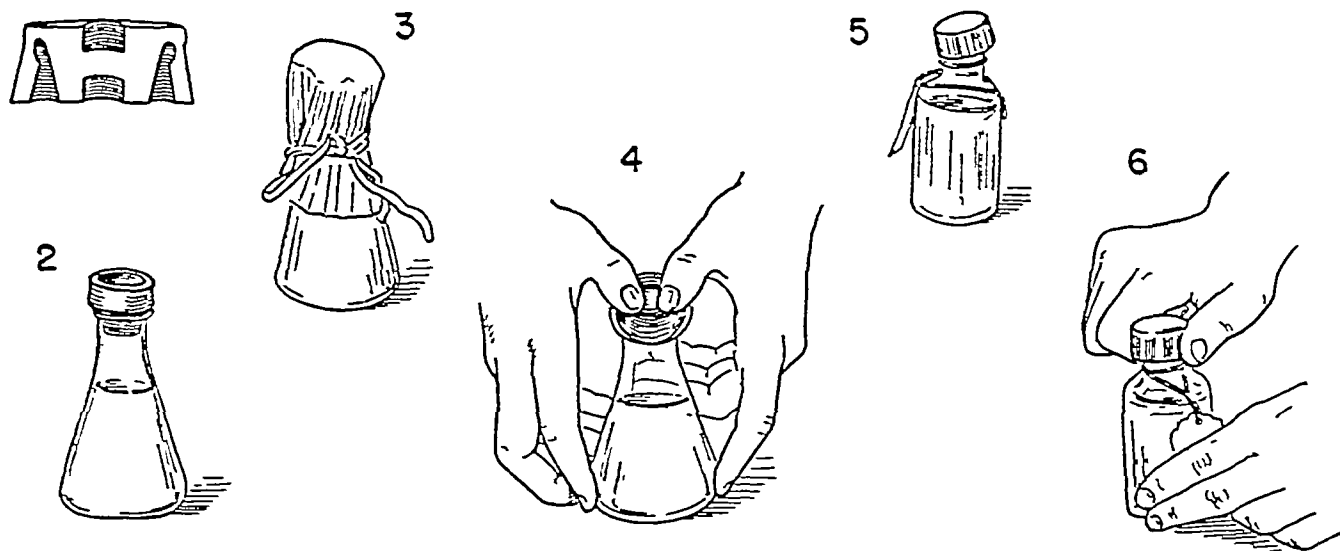


FIGURE 217

ure 217, 2, and a flaskhood is applied to prevent displacement during sterilization, figure 217, 3. After sterilization, the skirt is turned down to complete the seal, figure 217, 4. Fluid is removed either by puncturing the diaphragm or removing the stopper. After the diaphragm has been punctured, it can be punched out with a sharp cork borer and the stopper becomes a bushing that can be used to effect a closure with a steel stopper, figure 206, 3.

PROCAINE HYDROCHLORIDE

Solutions of procaine hydrochloride for local anesthesia must be isotonic to avoid damage to cells¹⁵ and tissue necrosis with consequent postoperative induration. For full anesthetic effect,¹⁶ procaine must be alkaline as the acid solution has but slight action.¹⁷ Alkaline solutions deteriorate so rapidly that they cannot be sterilized or

stored. Acid solutions, however, withstand sterilization^{18, 19} and can be stored indefinitely in hermetically sealed containers of hard glass. Procaine solutions should be crystal clear and colorless. The drug forms a white flocculent precipitate or collects as oily droplets at the surface at a pH greater than 8. Straw-colored or brownish tints are due to degradation to para-amino-benzoic acid and diethylaminoethanol.²⁰ Such solutions irritate tissues and have lost their maximum anesthetic effect.

Although procaine must be sterilized and stored in acid solution and administered as an alkaline solution, stable procaine solutions with full anesthetic effect can be provided readily in every operating room. Two solutions are necessary. A 1% solution made isotonic with sodium chloride serves as an ideal infiltration anesthetic, even though it has an acid pH, for the tissue fluids possess

¹⁵ GILMAN, S. Treatment of Dangerous Reactions to Novocaine, *N. E. J. Med.*, 219:841, 1938.

¹⁶ GROS, O. Ueber die Narkotika und Lokalanästhetika *Arch. f. Expt. Path. u. Pharm.* 63:81, 1910.

¹⁷ GERLOUGH, T. D. Influence of pH on Activity of Certain Local Anesthetics as Measured by the Rabbits' Cornea Method, *J. Pharmacol. & Expt. Ther.*, 41:307, 1931.

¹⁸ BARLOW, O. W., Winthrop Chemical Co., Inc. Personal communication, October 1, 1940.

¹⁹ SCHOU, S. A. and HENR, E. Decomposition of Cocaine Solutions upon Sterilization and Storage, *Pharma Acta Helv.*, 10:31, 1935. Abstracted by S. Waldbott in *Chemical Abstracts*, vol. 29, pt. III, p. 8236, 1935.

²⁰ Winthrop Chemical Co., Inc. Rensselaer, New York. Personal communication.

sufficient buffer to shift the reactions of the injected fluid to an alkaline pH. Hence, the anesthetic property is developed in the tissues themselves.²¹ Unfortunately, large nerves do not contain sufficient tissue fluid to exert this buffer action and alkaline novocaine must be injected.²¹ This can be done easily by adding the alkali immediately before injection just as many surgeons add epinephrine hydrochloride solution (1:50,000) to delay absorption of the anesthetic and to prolong its action three or more times.²²

Preparation of Solutions of Procaine

To avoid an alkaline pH at the solution glass interface, hard glass containers* must be used. If these are hermetically sealed, the novocaine can be stored indefinitely with but minor loss (2% during 8 years¹⁹). The bottles must be thoroughly cleansed, rinsed with pyrogen free distilled water and inverted to drain dry.²

The 1% solution (pH 2.9) is made by dissolving 10 grams of procaine hydrochloride and 7.5 grams of C.P. sodium chloride in a liter of boiling hot freshly distilled water containing 0.1 cc of 10 N hydrochloric acid. After solution is complete, 50 cc quantities are transferred to clean bottles. If screw cap bottles are used, the caps are started on but not turned down tightly (figure 217, 5). Plastic caps of Beetle or Durez withstand sterilization, figure 122.

The alkaline solution is made by diluting 1 cc of 10 N sodium hydroxide to 100 cc with freshly distilled water. This solution is transferred into clean 20 cc serum bottles

with the aid of a syringe and a 16-gage needle. The bottles are stoppered with rubber stoppers and as much air as possible is aspirated from them through a fine needle which is affixed to a 5 cc syringe and inserted through the stopper. Evacuation of the air prevents the stoppers from being blown out during sterilization.

Sterilization

The bottles are sterilized by exposure to saturated steam for thirty minutes after the temperature in the exhaust line has reached 121°C. After the sterilizer has cooled, the screw caps are tightened, figure 217, 6, hermetically sealing the bottles.

Use of Procaine Solutions

Potent solutions of procaine can be spoiled as they are being used by the alkali leached from the inside of the barrel of the syringe. Rinsing the syringe with sterile saline or distilled water will prevent the degradation of the procaine.

For infiltration anesthesia, the solution can be used as it comes from the bottle. For nerve block, 1.5 cc of the 0.1 N sodium hydroxide are aspirated from the vial with a syringe and added to a full bottle (50 cc) of procaine to render it alkaline and develop its anesthetic properties.

For spinal anesthesia, the best solvent for procaine is the patient's own spinal fluid which buffers the drug before it is injected intrathecally.

MORPHINE SULFATE

To have morphine available for instant injection it is convenient to provide it in sterile solution in rubber stoppered vials whence it can be quickly withdrawn into a sterile syringe.²

Like procaine morphine is unstable in alkaline solution accordingly it must be

* Dr. TAKAMI, G. Preparation of Local Anesthetic Solutions, *Bull. Am. Coll. Surg.* 1:140, 1933.

* PETER, R. N. Applied Pharmacology of Local Anesthetics, *Am. J. Surg.*, 34: 601, 1936.

Corning Glass Works, "Bor-on Rousch," Catalog No. 650.

made up with hot, freshly distilled water and kept in hard glass containers. Properly sterilized and sealed, morphine solutions can be stored for several months without appreciable loss of narcotic action. Satisfactory formulae for solutions of morphine are

Morphine hydrochloride	0.10 gm
Dilute hydrochloric acid, U.S.P.	0.05 cc
Distilled water to	10.00 cc

or

Morphine hydrochloride	1.0 gm
Para-chloro-meta-cresol	0.1 gm
Distilled water to	100.0 cc

The solutions are bottled in 20 cc. hard glass serum bottles. The bottles are stoppered with rubber serum stoppers, the residual air is evacuated through a fine needle and sterilized by exposure to saturated steam at 121°C for thirty minutes.

One cc. of either solution contains 10 mgm. of morphine hydrochloride. If sterile 1.5 cc. syringes are provided with the bottles of solution, the danger of accidental overdosage is minimized.

Atropine sulfate cannot be preserved in solution because it deteriorates rapidly. Where a solution containing both atropine and morphine is desired for pre-anesthesia medication, it may be prepared by the following formula.

Morphine HCl	0.10 gm
Atropine sulfate	0.06 gm
Dilute HCl U.S.P.	0.05 cc
Distilled water to	10.00 cc

This solution is sterilized as described but must be used within twenty-four hours.

ARSENICALS

The preparation of the various arsenicals for intravenous injection requires sterile, pyrogen-free distilled water and apparatus. These essentials can be controlled as previously described. Instructions for the actual preparation of the solutions accompany

every ampoule of arsenical and should be followed in detail.

SODIUM TETRAIODOPHENOLPHTHALEIN

Alkaline solutions of this drug are relatively stable when protected against absorption of carbon dioxide. The drug precipitates from acid solutions. Alkaline solutions are clear and purplish red.

A suitable solution for intravenous injection is prepared by dissolving 2.5 grams in 28 cc. of hot, freshly distilled water in a clean bottle. Shaking or cooling hastens the absorption of carbon dioxide and must be avoided. The screw cap is put on loosely and the bottle is sterilized immediately as described for procaine. Sterile, hermetically sealed solutions can be stored indefinitely. Bottles containing sodium tetraiodophenolphthalein should not be shaken prior to use as this stirs up the sediment, which settles out of unfiltered solutions as they cool. Solutions in which a gross precipitate appears should be discarded.

WATER STERILIZERS

Hospitals are equipped with large tanks in which water can be sterilized and routines for the operation of such sterilizers have been elaborated because the idea that water is difficult to sterilize has become entrenched in surgical thought. The contrary is true. Water contains but few spores and those are wet. Penetration is not a problem as with dry goods. There is no problem of air clearance. Yet, most hospitals spend much more money on water sterilizers than they do for equipment for the sterilization of instruments or dry goods. Those who recognize that water is easy to sterilize condone the expenditure for water sterilizers on the grounds that the sterilizers provide for safe storage of sterile water, overlooking the fact that there is no practicable way of guarding the sterilizers against

contamination and that the water is likely to be contaminated when it is drawn off

Those who believe in providing a physiological environment for wound healing recognize instantly that sterile tap water cannot be used as ideal irrigating fluid. Even "normal saline" solution has been shown to exert a poisonous action on tissues and only solutions such as those advocated by Cushing and Ringer should be used in the operating room. These entail the use of distilled water as a diluent for the necessary electrolytes essential to an isotonic solution. Isotonic solutions are most easily bottled, sterilized, stored, and dispensed as described previously.

Where water sterilizers are used, the following limitations must be considered. No positive way has been devised to sterilize the draw-off faucet where dry spores are likely to be deposited or to guard its sterility against insect or contact contamination until the entire contents of the storage tank have been used. Then, too, a reliable method for removing bacteria from the air which must be admitted to the sterilizer as water is drawn off has not been found. Water sterilizers are fitted with vents, figure 218, so that air can be discharged during filling and sterilization. Usually a thermostatic responsive valve is provided to close the tank so that steam pressure can be developed during sterilization. As the tank cools, this valve opens so that air can rush in to overcome the negative pressure caused by drawing off water. As this air rushes in, it inevitably carries with it air borne bacteria to contaminate the contents of the tank²² because the various filtering or scrubbing devices are not effective.

Another problem in the water sterilizer is that of sterilizing the inside of the gage glass. Older sterilizers are fitted with con-

CONTAMINATION OF STERILE WATER

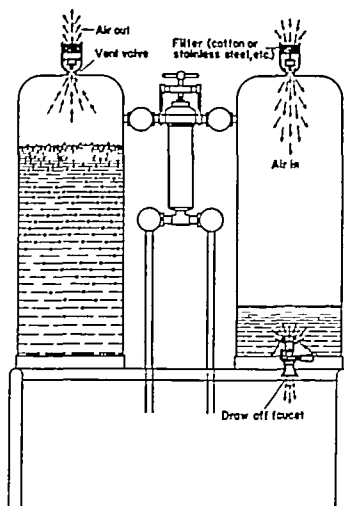


FIGURE 218

ventional side arm gage glasses, illustrated in figure 219, 1, where the fluid in the glass does not circulate and hence remains cool and is not sterilized. Sterilization is provided for by a routine of opening the valve at the top of the gage glass and closing that at the bottom so that the unsterile water can be drained from the petcock in the bottom fitting to permit steam to blow through during sterilization. While this technic provides for sterilization of the gage glass it is often neglected in practice.

Some water sterilizers are fitted with water level gages of the dial type figure 219, 2 in which the weight of the water in the tank actuates a diaphragm to indicate the degree of filling. This type offers no problem in sterilization.

²² MOORE, E. W. and MITCHELL, R. D. Air Filters for Surgical Water Sterilizers. Personal communication, 1938.

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²² Moore, E. W. and Mitchell, R. D. Air Filters for Hospital Water Sterilizers. Personal communication, 1938.

CONTAMINATION OF STERILE WATER

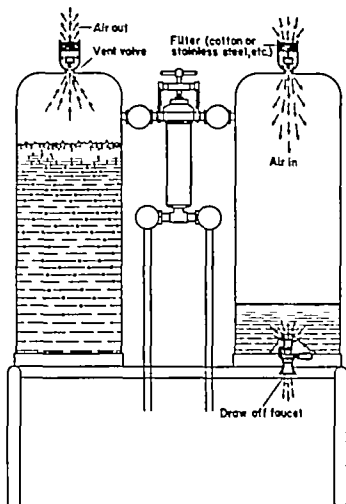


FIGURE 218

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STERILIZING GAGE GLASS

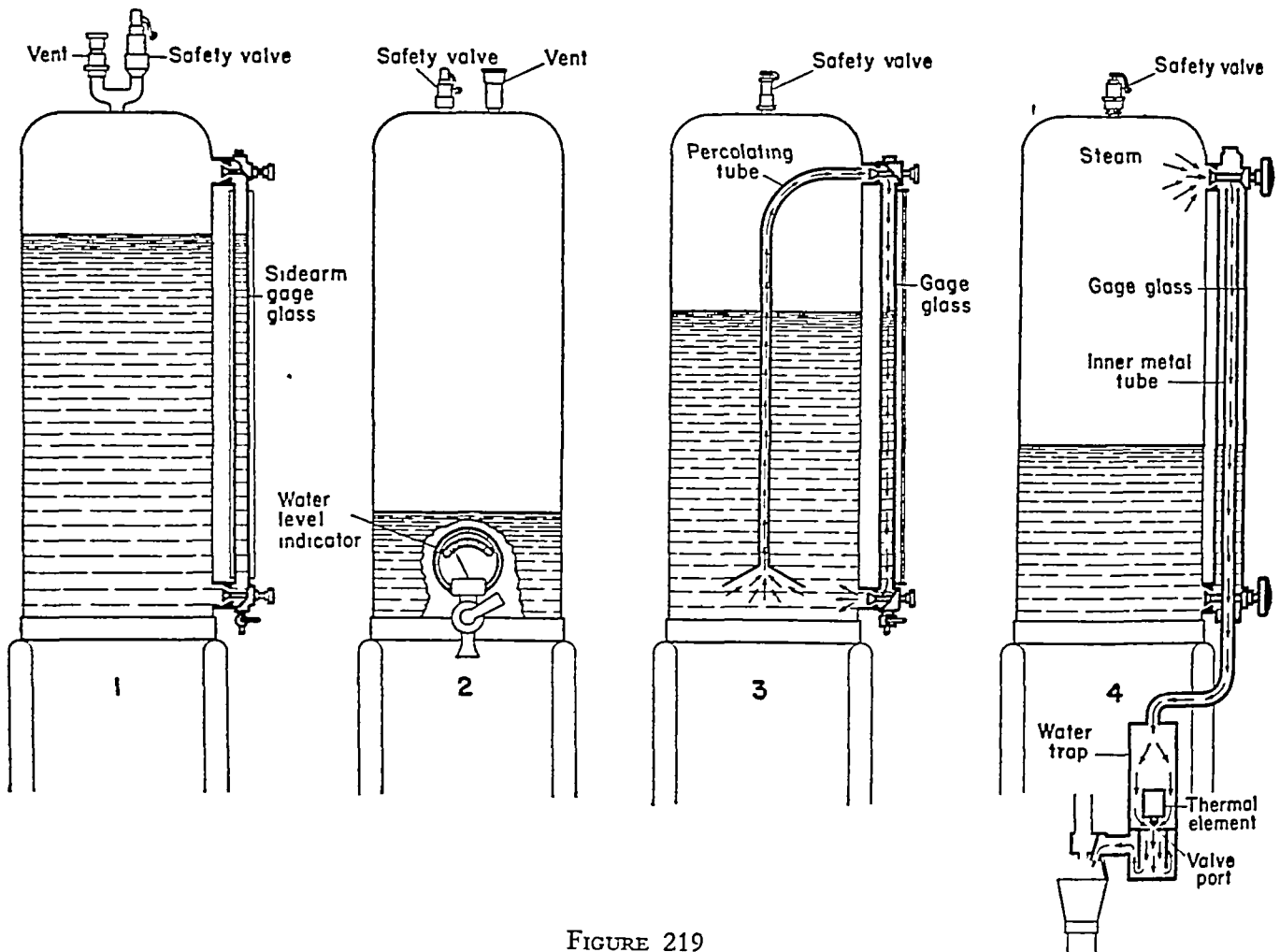


FIGURE 219

Another type of construction provides for positive circulation of the water through the gage glass much as the coffee in a percolator is carried from the heating coil in the bottom of the pot and percolated over the top of the coffee above. Figure 219, 3, illustrates a percolating tube which carries the hot water from the neighborhood of the heating coils to the top of the gage glass whence it circulates downward and back into the tank. This device is automatic and provides sterilization routinely.

Figure 219, 4, illustrates a design which simultaneously provides for sterilization of the gage glass and venting of the tank through a water trap in the endeavor to filter bacteria out of the intruding air when water is drawn. In this type, air and

steam are discharged through a tube located in the center of the gage glass. When the air has been completely discharged, the thermal element closes and steam inside the tube heats the water surrounding it to sterilize the gage glass. Simultaneously, the water trap is sterilized and filled with distilled water. After the water tank has cooled, the thermal element opens and air can be drawn through the water trap, which contains porcelain beads to break up the air into small bubbles with the idea that dust and bacteria are removed. Dry bacteria ride the bubbles through such a trap, however.²³

Some of the problems considered under sanitary plumbing in Chapters VI and VII also affect water sterilizers. Leakage of

SAFE WATER SUPPLY

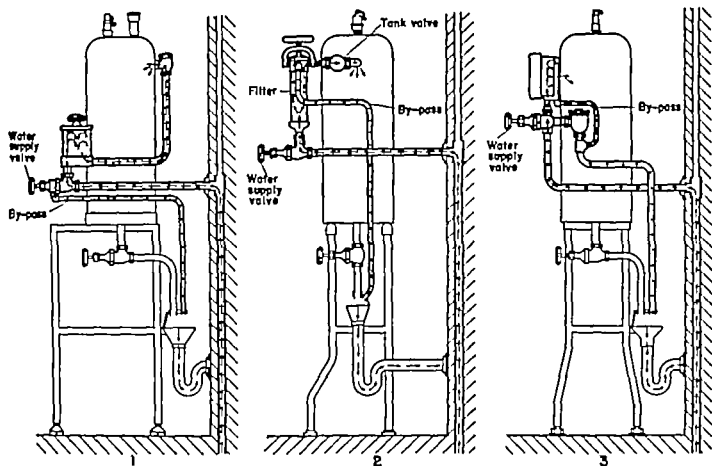


FIGURE 220

SOURCES OF CONTAMINATION IN WATER STERILIZER

raw water past faulty valves is a source of potential contamination unless the sterilizer is designed to prevent such an occurrence. In figure 220, 1, leakage insufficient to support a head of water in the inlet pipe is led directly from the valve to the drain through a by pass. In figure 220, 2, a by pass is provided on the top of the filter which effectively takes care of leakage provided the tank valve is tightly closed. In figure 220, 3, leakage is conducted to the drain through a by pass from the bottom of the filter so that a leak obvious through the window in the filter would have to occur to cause pollution. Figure 221 shows another way in which raw water and even water from the drain may contaminate a sterile tank. The illustration indicates sterile water in tank A and tank B being filled with tap

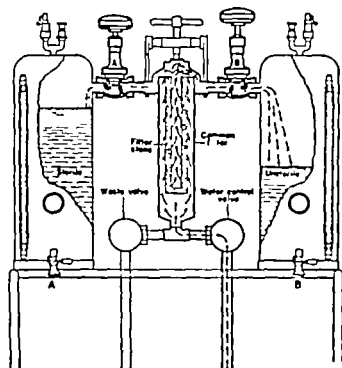


FIGURE 221

PROTECTED WASTE

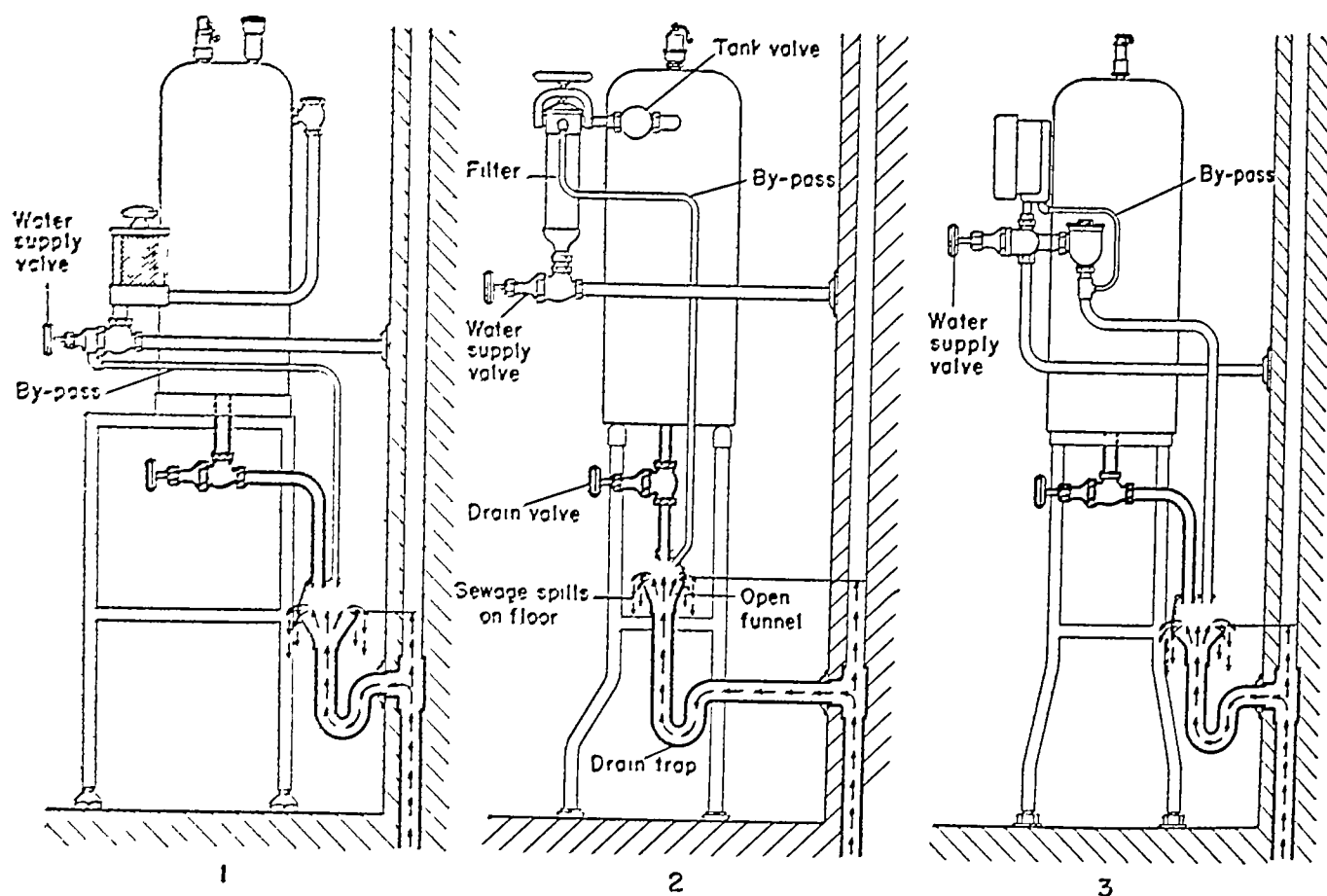


FIGURE 222

water through a common filter. Because valve *A* leaks slightly, raw water is forced into the sterile tank. Even if both tanks have been sterilized, this accident is likely to happen when the waste valve has not been opened to care for any leakage past the water control valve. In some installations, it is even possible for negative pressure in the water tank to aspirate air or water through an open waste valve that is connected directly to the drain. Open funnels must be provided to protect water sterilizers against contamination from the drain, figure 222. Many sterilizers with direct connections with the drain are still in use and constitute a grave hazard.

Water sterilizers present a hidden danger that is seldom suspected when unsterile water is found. Each tank is equipped with

a coil through which tap water is circulated to cool the hot, freshly sterilized water so that it can be used promptly. This coil may develop a leak and contaminate the sterile water during the cooling cycle.

Much effort has been expended in developing methods for filtering the water before it is introduced into the water sterilizers. These filters are intended to remove particulate matter only and do not remove chemicals which are dissolved in the water as is often assumed. Older sterilizers are fitted with porous porcelain filters. These are unsatisfactory because they crack frequently, particularly when leaky valves, figure 221, permit steam to contact the stone. Now, more satisfactory filters of cotton cord or compressed fiber are available. Some installations are unsatisfactory

because no provision has been made for the sterilization of the filters and pyrogenic organisms grow in the moist filter and pollute the water. Others provide for flushing the filter in a reverse direction with steam each time the water is sterilized so that this type of pollution is eliminated.

Because there are many types of water sterilizers in common use, it is impossible to give any more than general instructions for sterilizing the water. Little more is needed than simply heating the water to boiling to effectively sterilize the fluid itself. Steam under pressure, however, must be developed in those which depend upon steam for the sterilization of the gage glass.

Many water sterilizers are fitted with a condenser so that steam can be taken from the top of the water tank and condensed to form distilled water. This type of distilled water is unsatisfactory for intravenous use because the distillation is too crude to eliminate pyrogens, unless the water in the

tanks is heated for thirty minutes at 140°C before the steam is drawn off.*

Water sterilizers present a grave personnel problem. Attendants are seldom versed in proper operation and often fail to recognize faulty function or poor maintenance. The sterilizers are a constant invitation to idle bystanders to play with the numerous valves. Hence, sterility of the water can only be relied upon when sufficiently close supervision is enforced to control the marginal help hospitals must employ. In summary, then, water sterilizers are decided luxuries that contribute little to aseptic technic.

Recent attempts¹¹ to perfect the application of ultraviolet radiation for the disinfection of water seem promising. The equipment is relatively inexpensive and many of the limitations of the water sterilizer discussed are overcome.

* LUCKEY, M. and HOLLADAY, L. L. Disinfecting Water by Means of Germicidal Lamps, *General Electric Review* 47:45-50 April, 1944.

CHAPTER XVII

BLOOD AND PLASMA FACILITIES

Blanched by profuse haemorrhage, which no adequate means had been employed to suppress, but which had now ceased, she was lying on her back in a state of imperfect consciousness, with the pulse at her wrist barely perceptible
deceitful promises of reaction were succeeded by progressive indications of sinking *I was provided with the apparatus necessary for performing transfusion, and having obtained willing supply of blood from three of the patient's kind-hearted neighbors, I opened a vein at the bend of the elbow* *we had the very perfect gratification of witnessing not only the complete restoration of the circulatory power, but the return of consciousness*

— RICHARD OLIVER, 1840¹

The widespread use of blood and its derivatives as therapeutic agents is an outstanding contribution of World War II to the better care of medical and surgical patients. In a few short months, the concept of assisting homeostasis has been disseminated throughout the profession. Techniques for supplying adequate amounts of blood and plasma have been elaborated and most important of all, the general public has been so well educated to the idea of donating blood that the American Red Cross collected 100,000 bottles of blood each week from voluntary donors. The whole movement has been so rapid and complete that it is almost impossible for a hospital to provide modern care without the advantage of stores of blood and plasma. The technical aspects of processing the blood are simple and straightforward and no longer require elaborate equipment. The procurement of donors, however, is a challenge in public

relations and requires careful planning and organization in order to maintain a steady supply of blood from good neighbors in the community. In a hospital where the staff is tuned to obtaining a high percentage of autopsies, the public relations are such that there is usually no difficulty in obtaining more donors than are necessary.

Because a steady supply of blood is more advantageous than bursts of donors which overwhelm the technicians in a blood bank, it is best to arrange for donors on an individual basis rather than attempt to solicit large groups. The most satisfactory results can be obtained by establishing the custom of expecting every patient admitted to the hospital to suggest the names of two relatives or friends who are willing to donate blood. The response is usually gratifying but it has been found that the number of donors who actually appear for phlebotomy is disappointing unless liaison is maintained with the prospective donor. The appointment card shown in figure 223, 1, has proved satisfactory. On the reverse side of the card, figure 223, 2, the donor is given instructions which result in blood which contains a

¹ OLIVER, RICHARD. Case of Dangerous Uterine Hemorrhage in Which Transfusion Was Successfully Employed with Some Observations on the More Frequent Expediency of That Operation, *Edinburgh Med & Surg J*, 54 406-411, 1840, Oliver and Boyd

FORMS FOR BLOOD BANK

APPOINTMENT CARD

for
BLOOD DONATION

PETER BENT BRIGHAM HOSPITAL, BOSTON

Name of donor _____

Name of patient _____ Ward _____

Date _____ Hour _____

Room _____ Home Officer _____

2

IMPORTANT

You must not eat for 4 hours before your appointment. Black coffee, clear tea or fruit juice permissible. Absolutely NO milk, cream, butter or fat of any kind.

If you do not follow these instructions, your blood will be unsuitable for use. If you are unable to keep this appointment, please notify us at once or failure to do so will cause our staff to have valuable time. Donors between the ages of 18 and 21 must bring written permission of parent or guardian.

N. A. WILKIN, M. D.

Superintendent

6

BLOOD BANK

PETER BENT BRIGHAM HOSPITAL

The following suggestions are made for your guidance:

1. DRESSING: Keep it on for 24 hours and keep it dry.
2. DIET: A normal diet with meat and vegetables is adequate. Special food are unnecessary. We urge you not to eat except what we give you for one half hour after leaving the Blood Bank.
3. SMOKING: Do not smoke until after you have eaten.
4. ACTIVITY: Resume your usual activities immediately. You may feel somewhat tired or sleepy tomorrow. Avoid over-exertion for 12 hours.
5. The skin about the needle puncture may become discolored. This is due to the leakage of two or three drops of blood from the punctured vein. It is not dangerous and disappears spontaneously in several days.
6. You will receive a donor's identification card by mail recording your contribution and the type of your blood.
7. Another donation of blood may be made after two months.

Your blood is an important contribution to the welfare of the community served by the Peter Bent Brigham Hospital. Speaking for those whose lives it will save, I wish to express my sincere appreciation for your co-operation.

N. A. WILKIN, M.D.

Superintendent

3

Children Hospital Peter Bent Brigham Hospital
BLOOD BANK

This is to certify that _____

has donated blood on the following dates:

The donor's blood is International Group _____

RH _____

Sex _____

4

BLOOD DONOR REGISTRATION CARD

PETER BENT BRIGHAM HOSPITAL

CHILDREN'S HOSPITAL

Mr _____	Serial No. _____
Miss _____	Date _____
Name Mrs. _____	
Address _____	
Telephone No. _____	Birth _____
City _____	State _____
Zip _____	
Temperature _____	Pulse _____
Hemoglobin _____	% Blood Pressure _____
Refused _____	c. c. withdrawn _____
Diagnosis _____	Recipient _____
Postponed _____	File card in _____
Ke blood taken _____	active donor list _____
Crossmatch _____	
Four veins _____	Phlebotomy by _____
Informed _____	
Signature _____	
Reasons _____	
Blood Group <input type="checkbox"/> O <input type="checkbox"/> A <input type="checkbox"/> B <input checked="" type="checkbox"/> M <input type="checkbox"/> AB <input type="checkbox"/> Rh - neg <input checked="" type="checkbox"/> M <input type="checkbox"/> pos <input type="checkbox"/> RH - neg <input type="checkbox"/> M	

○ ○ ○

○

5

HAVE YOU HAD

Any Serious Illness? _____	Coughed Up Blood Recently? _____
Illness in the Last Month? _____	Shortness of Breath? _____
Syphilis? _____	Jaundice? _____
Malaria? _____	Swelling of the Feet? _____
Tuberculosis? _____	Fainting Spells? _____
A Persistent Cough? _____	Convulsions? _____
Pain in the Chest? _____	When did you last donate blood? _____
Remarks _____	

I hereby consent to the withdrawal of my blood as a donation to the Blood Bank of the Peter Bent Brigham Hospital and Children's Hospital.

Signature _____

Address _____

City _____

State _____

Zip _____

Telephone _____

minimum of lipoids. If the appointment for phlebotomy is delayed for more than a week, a follow-up postcard is worth while as a reminder. Such a card should also bear the instructions essential to having the donor in suitable condition for phlebotomy.

It is best to organize regular clinics where 15 or 20 donors are bled in the course of several hours. The chief factor in the success of these clinics is to take the donors the instant they arrive and process them in a businesslike manner immediately. Delays not only waste the donor's time and make him reluctant to return but the psychic trauma of waiting around results in unhappy reactions. Once asked for blood, some donors do not like to postpone their donation but wish to give immediately. It is best to accommodate such individuals. Roughly half of the donors serviced at the Peter Bent Brigham Hospital blood bank are handled on this basis.

The first step in processing a donor is to obtain vital information for identification and the determination of his suitability as a donor. A satisfactory form is illustrated, figure 223, 4. The obverse side provides space for comments by the phlebotomist and most important of all, a space indicating whether or not the donor wishes his name filed in the active donor list. By routinely asking this question, it is very easy to build up a large list of donors who willingly respond when the usual channels for obtaining donors are momentarily unsuccessful. There is also a space for laboratory data on this side of the card. These data are recorded by punching out the appropriate squares with a punch bearing the technician's initials. The record is permanent and is not effaced readily by accident, or dishonestly changed to cover a careless cross-matching which has resulted in an unfortunate transfusion reaction. The holes near the edge of the card provide for ready

selection of donors of various types. The appropriate hole is converted to a notch by punching out the edge of the card. When a group B donor is wanted, for example, a knitting needle is simply inserted through the B hole and the stack of cards is shaken gently. Because the B cards have a notch in place of the hole, they fall out of the stack and are instantly available. The reverse side, figure 223, 5, of the card presents the medical data necessary for the proper selection of donors.

Criteria which have proved satisfactory for the selection of donors are those elaborated by the American Red Cross Blood Donor Service ² (See page 311.)

Following phlebotomy, the patient should be given specific instructions for the care of the phlebotomy wound, diet, exercise, and the like, figure 223, 6. It is best to have these instructions printed to preserve uniformity and to militate against the building up of elaborate folklore concerning aftercare which causes rumor and frightens prospective donors away. A card, thanking the donor for his blood and notifying him of his blood group, should be mailed as a gracious gesture, figure 223, 3. This card often results in return appointments.

The choice of the equipment and technic for the processing of the whole blood and plasma should be decided on the basis of local need and resources rather than sales arguments extolling supposed technical advantages. Any of the accepted equipment yields good results only if sound bacteriologic technic is rigidly enforced. Spoilage of blood and contamination are rare in a blood laboratory where a single person is held responsible for all aspects of the technic.

Most hospitals can advantageously install the technic described here because any

² TAYLOR, E. S. Procurement of Blood for the Armed Forces, *J. A. M. A.*, 120: 119-123, 1942.

CRITERIA FOR SELECTION OF BLOOD DONORS

AGE	Donors between the ages of 18 and 59 are acceptable. Those 18 through 21 must have the written permission of a parent or legal guardian. If married, permission of the mate is desirable.
SEX	Both sexes are taken indiscriminately.
WEIGHT	Those weighing less than 110 pounds should be rejected if a 500 cc. donation is desired. It is usually uneconomical to perform phlebotomy with the expectation of taking less than 500 cc.
PREGNANCY	Do not perform phlebotomy during pregnancy or for nine months after any type of termination.
TEMPERATURE	The oral temperature must be below 99.6°F.
HEMOGLOBIN	Hemoglobin must be above 12.3 grams by the copper sulfate specific gravity method. ²
BLOOD PRESSURE	Donors are accepted with systolic blood pressures lying between 100 and 200 mm. of mercury. The diastolic pressure, read in the second phase, must be below 100.
PULSE	Those with bradycardia under 50 or tachycardia over 100 or any type of irregularity are rejected.
ILLNESS AND SURGERY	The patient's physician is consulted in each instance to avoid professional criticism as well as to obtain confidential contraindications which are unknown to the patient. Serious illness usually unfits the patient for blood donation for six months. Minor surgical procedures, such as tooth extraction or tonsillectomy, are contraindications until the operative site has healed because bacteremia is likely to exist. Recent vaccination or immunization does not disqualify the prospective donor.
HISTORY	A positive answer to any of the symptoms indicating epilepsy, heart disease, diabetes, syphilis, undulant fever, malaria, or tuberculosis is cause for routine rejection. Those who have had jaundice at any time or who have been exposed to patients with infectious jaundice are rejected. Donors who have had virus infection, such as dengue or yellow fever and virus pneumonia, should not be accepted until six months have elapsed.

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hospital where major surgery is done usually has the necessary equipment and sufficiently intelligent personnel to avail itself of the economy of processing blood for a total cost approximating \$2.45 per unit. The principles of cleansing and sterilization of apparatus and preparation of the essential solutions have already been outlined in Chapter XVI.

CENTRIFUGE TECHNIC — GRAVITY METHOD

The outstanding advantage of the centrifuge technic is the preparation of plasma

which is diluted by minimal amounts of sodium citrate and dextrose solutions.

The collection of blood is most satisfactorily performed with a simple gravity collecting set depending upon venous pressure and gravity to secure an ample flow of blood.

Materials Required

1. An anticoagulant and preserving solu-

² PHILLIPS, R. A., VANSLYKE, D. D. Preliminary Report on the Copper Sulfate Method of Hemoglobin Determination, *Bull. U. S. A. Med. Dept.*, 1:156 December 1943.

tion containing the following chemicals is prepared.^{4, 5}

Trisodium Citrate $\text{Na}_3\text{C}_6\text{H}_5\text{O}_7 \cdot 2\text{H}_2\text{O}$	1.33%
Citric Acid $\text{C}_6\text{H}_8\text{O}_7 \cdot \text{H}_2\text{O}$	0.47%
Dextrose $\text{C}_6\text{H}_{12}\text{O}_6$	3.00%

This "ACD" solution is easily made by putting the following components into a counterbalanced 2.5 liter flask

Sodium Citrate (Dihydrate)	26.66 Gm
Citric Acid (Monohydrate)	9.40 Gm
Dextrose (Anhydrous)	60.00 Gm

Freshly distilled water is added to a net weight of 2030 grams. This solution is filtered through a sintered glass filter into a large burette, whence 125 cc. quantities are measured into clean 650 cc centrifuge bottles. The bottles are stoppered and sterilized for thirty minutes at an exhaust line temperature of 121°C. When hermetically sealed, the solution can be stored indefinitely. One-half liter of blood can be preserved for twenty-one days in ACD solution with a loss of function of but 20% of the erythrocytes.⁶

2 A container for filtering whole blood prior to administration is prepared by putting one cc. of distilled water into a clean 650 cc bottle. The water furnishes the steam essential for sterilization. After exposure to saturated steam at 121°C for thirty minutes, the bottle is sealed and stored until used.

3 A four-liter pooling flask with 5 cc of distilled water added to insure sterilization is exposed to saturated steam at 121°C for thirty minutes.

4 A 650 cc container with 50 cc of 50% dextrose for storing plasma, is sterilized at

121°C for thirty minutes and hermetically sealed.

The container in which the blood is collected must be specially designed to withstand the force encountered in a centrifuge. The container illustrated in figure 244, 2, fulfills this purpose in that the walls are extra heavy and are molded so that they are thicker at the bottom than at the top. The function of the dimple in the bottom is to exert sufficient downward thrust in the centrifuge so that the bottom of the bottle does not buckle inward to the point of fracture under the downward thrust of the walls. The divergently tapering walls and dome-shaped bottom also contribute to the technic because they force the shell of ice, which forms when plasma is frozen, to rise in the container rather than permit the expansion of the ice to crack the container.

Apparatus Required

1. Gravity blood collection kit is composed of 45 cm of rubber tubing (3 mm. bore \times 1.5 mm wall), a collecting tube assembly, a No. 14 gage needle, a needle holder with a No. 27 gage needle, and a medicine glass, and three test tubes (13 \times 100 mm) with corks. Assemble the elements of the apparatus as illustrated in figure 224, 7, and sterilize as instructed in Chapter XVI.

2 The filtration kit contains a stainless steel filter assembly, 2 pieces of rubber suction tubing 45 cm long (4.5 mm bore \times 2 mm wall), a side arm collection assembly, and a medicine glass. These parts are put together as shown in figure 229, 2, and sterilized.

3 The administration kit also has a stainless steel filter assembly with 100 cm of rubber tubing (3 mm bore \times 1.5 mm wall), a glass adapter, and a needle holder with No. 19 and No. 21 gage needles. Assemble parts as shown in figure 229, 3, and sterilize.

⁴ LOUTIT, J. F., MORRISON, P. L., YOUNG, I. M. and LUCAS, L. J. Citric Acid-Sodium Citrate-Glucose Mixture for Blood Storage, *Quart. J. Exper. Physiol.*, 32: 183, 1943.

⁵ GIBSON, J. G., II. Personal communication, November 1944.

⁶ GIBSON, J. G., II. Personal communication, April 1945.

GRAVITY TECHNIC FOR BLEEDING



FIGURE 224

4 The kit for pooling plasma consists of a side arm collection assembly with 2 pieces of suction tubing 45 cm long (4.5 mm bore \times 2 mm wall) and a stainless steel tube 30 cm long, and a medicine glass. Figure 230, 1, shows how these parts are assembled, prior to sterilization.

Equipment Required

1 Phlebotomy truck. Phlebotomy is facilitated by the use of a truck such as is shown in figure 225, 1. It provides the phlebotomist with all the essentials for servicing ten or fifteen donors. It is loaded in the central supply room, wheeled to the bleeding clinic and then to the blood laboratory. It transports the essential sterile equipment, germicides, and accessories to the donor, affords table space for assembling the kit, provides the sterile transfer forceps for handling the sponges moistened with germicides and four storage compartments for unused collecting sets and citrate containers, as well as full bottles of blood. Among the accessories are a sphygmomanometer, a stethoscope, 2 cc syringes of sterile novocaine, an emesis basin, jars containing sponges moistened with liquid soap, 2% aqueous iodine, and 70% alcohol, respectively, as well as dry sponges for the final dressing. A Pyrex tray* countersunk in the top of the truck serves as a receptacle for used tubing and needles. A clean tray is substituted after each donation so that when the truck is wheeled to successive donors, it is clean and neat.

2 Phlebotomy table. The donor is made comfortable in the supine position on a table fitted with a sliding arm board and wire basket to hold the collecting bottle and pilot tubes, figure 225, 2 to 4. In a clinic where many donors are handled simultaneously, much labor is saved and better care can be

taken of the donors by arranging them with their feet to the wall.

After the site for phlebotomy is determined, a sphygmomanometer cuff is applied in the reverse position, tubes presenting at the shoulder. The cuff is inflated to 50 mm Hg pressure and spring clamps are applied to occlude both tubes. The manometer is then disconnected. The skin overlying the antecubital fossa is then disinfected as described in Chapter XII. Several drops of 2% novocaine solution are injected intracutaneously.

The flask containing the ACD solution can be readied for phlebotomy simply by removing the stainless steel stopper and inserting the collecting tube assembly, figure 224, 2. The sterility of the stainless steel stopper is preserved by placing the stem in the sterile medicine glass which comes with the collecting kit.

Phlebotomy is performed through the wheal of novocaine. The blood flows by the aid of venous pressure and gravity through the needle and the short rubber tube to the stainless steel tube whence it dribbles into the citrate which is gently swirled to insure complete mixing. Venous pressure is maintained by instructing the donor to alternately clench and relax his fist about ten times per minute.

When 500 cc of blood have been collected, the pressure in the sphygmomanometer cuff is easily released by removing the spring clamps. The ears of the rubber bushing are grasped, figure 224, 3, and the stainless steel tube is removed from the glass collecting tube. As the stainless steel tube is withdrawn, care is taken to pick up any blood on the steel tube which adheres to the end of the glass, figure 224, 4. Before the needle is removed from the vein, two of the pilot tubes are filled with blood, figure 224, 5. About 2 cc of blood is run into the third tube containing an equal quantity

* Corning Glass Company, Corning, New York, Pyrex No. 212

EQUIPMENT FOR DONOR CLINIC

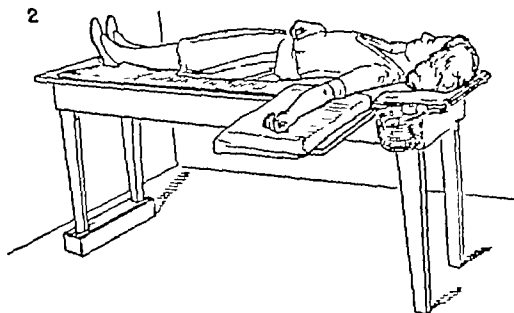
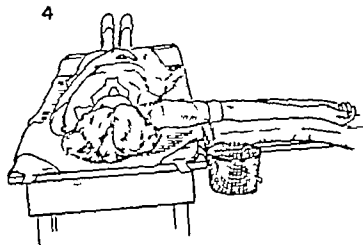
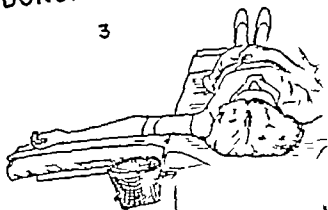
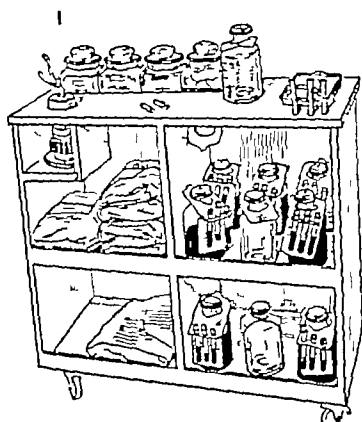


FIGURE 225

4. The kit for pooling plasma consists of a side arm collection assembly with 2 pieces of suction tubing 45 cm long (4.5 mm bore \times 2 mm wall) and a stainless steel tube 30 cm long, and a medicine glass. Figure 230, 1, shows how these parts are assembled, prior to sterilization.

Equipment Required

1. **Phlebotomy truck.** Phlebotomy is facilitated by the use of a truck such as is shown in figure 225, 1. It provides the phlebotomist with all the essentials for servicing ten or fifteen donors. It is loaded in the central supply room, wheeled to the bleeding clinic and then to the blood laboratory. It transports the essential sterile equipment, germicides, and accessories to the donor, affords table space for assembling the kit, provides the sterile transfer forceps for handling the sponges moistened with germicides and four storage compartments for unused collecting sets and citrate containers, as well as full bottles of blood. Among the accessories are a sphygmomanometer, a stethoscope, 2 cc syringes of sterile novocaine, an emesis basin, jars containing sponges moistened with liquid soap, 2% aqueous iodine, and 70% alcohol, respectively, as well as dry sponges for the final dressing. A Pyrex tray* countersunk in the top of the truck serves as a receptacle for used tubing and needles. A clean tray is substituted after each donation so that when the truck is wheeled to successive donors, it is clean and neat.

2. **Phlebotomy table.** The donor is made comfortable in the supine position on a table fitted with a sliding arm board and wire basket to hold the collecting bottle and pilot tubes, figure 225, 2 to 4. In a clinic where many donors are handled simultaneously, much labor is saved and better care can be

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After the site for phlebotomy is determined, a sphygmomanometer cuff is applied in the reverse position, tubes presenting at the shoulder. The cuff is inflated to 50 mm Hg pressure and spring clamps are applied to occlude both tubes. The manometer is then disconnected. The skin overlying the antecubital fossa is then disinfected as described in Chapter XII. Several drops of 2% novocaine solution are injected intracutaneously.

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Phlebotomy is performed through the wheal of novocaine. The blood flows by the aid of venous pressure and gravity through the needle and the short rubber tube to the stainless steel tube whence it dribbles into the citrate which is gently swirled to insure complete mixing. Venous pressure is maintained by instructing the donor to alternately clench and relax his fist about ten times per minute.

When 500 cc of blood have been collected, the pressure in the sphygmomanometer cuff is easily released by removing the spring clamps. The ears of the rubber bushing are grasped, figure 224, 3, and the stainless steel tube is removed from the glass collecting tube. As the stainless steel tube is withdrawn, care is taken to pick up any blood on the steel tube which adheres to the end of the glass, figure 224, 4. Before the needle is removed from the vein, two of the pilot tubes are filled with blood, figure 224, 5. About 2 cc of blood is run into the third tube containing an equal quantity

* Corning Glass Company, Corning, New York, Pyrex No. 212

EQUIPMENT FOR DONOR CLINIC

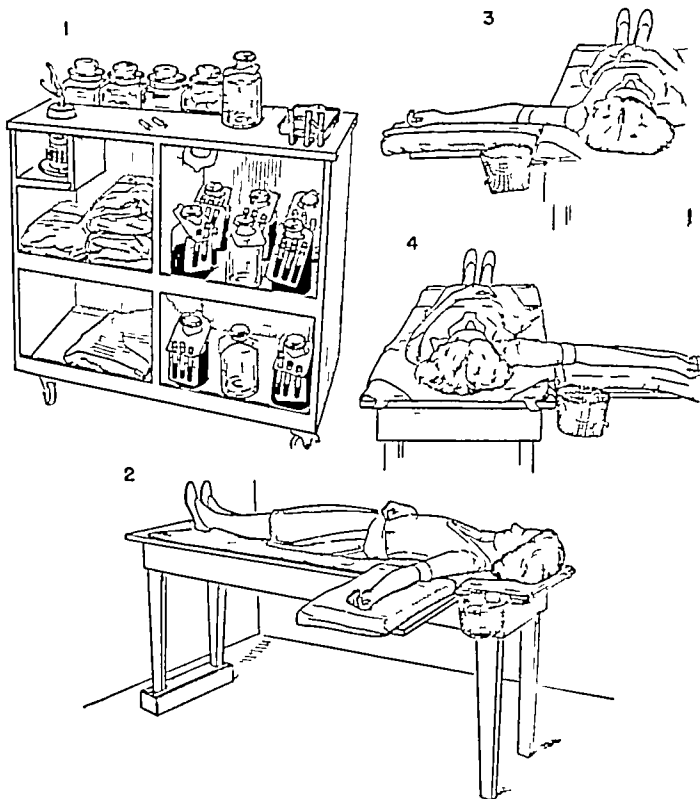


FIGURE 225

TAGS FOR BLOOD AND PLASMA

1

RETURN THIS TAG TO BLOOD BANK
WITH USED EQUIPMENT

Do NOT infuse after.....

☐ ☐ ☐
☐ ☐ ☐

CITRATED HUMAN BLOOD
I certify that the donor appears to be free of disease transmissible by blood transfusion on this date.

(Licensing Physician)

(Date) (Serial No.)

Donor's Name _____

<input type="checkbox"/> Negative	} Serology	<input type="checkbox"/> O
<input type="checkbox"/> Positive		<input type="checkbox"/> A
<input type="checkbox"/> Negative	} Blood Group	<input type="checkbox"/> B
<input type="checkbox"/> Positive		<input type="checkbox"/> AB

Poolled — date _____ Pool Number _____ ☐

Recipient's name _____

Recipient's blood group ☐ O ☐ A ☐ B ☐ AB

RH— Negative ☐ Positive ☐

Cross matched by _____

Infused by _____ Date _____

Reaction? _____ Describe _____

Checked by business office ☐

CITRATED HUMAN BLOOD

Contains

a. sterile anticoagulant and preservative solution.	
sodium citrate	1.66 gms.
citric acid	588 gms.
dextrose	3.75 gms.
distilled water	qt. 125 cc.
b. Human Blood	qt. 625 cc.

Drawn and filtered under aseptic precautions.

INSTRUCTIONS
Do not infuse hemolyzed blood.
Always filter this blood as it is being infused.
Shake thoroughly to resuspend the red blood cells.
The blood must be infused immediately upon receipt from the blood bank. Do not heat the blood. If special circumstances make the use of warm blood desirable, have it heated at the blood bank.

2

FROZEN HUMAN PLASMA

POOL NUMBER _____ Date _____ ☐

Bottle Number _____

14 Day Culture Negative _____ ☐

Bottled & Frozen _____ Date _____ ☐

Recipient's Name _____

Infused by _____ Date _____

Reaction? _____ Describe _____

Checked by Business Office _____ ☐

RETURN THIS TAG TO BLOOD BANK WITH USED EQUIPMENT (over)

FROZEN HUMAN PLASMA

Contains

a. sterile 10% solution of dextrose	50 cc.
b. sterile plasma from a pool containing clear plasma from at least 8 apparently healthy donors.	100 cc.

INSTRUCTIONS
Thaw the frozen plasma by exposing it to an environment NO WARMER than 37° C. Temperatures in excess of this will cause precipitation of fibrinogen. Shake thoroughly and let plasma stand in the liquid state for approximately one half hour before it is infused. Plasma must be filtered during infusion.

of sterile ACD previously added from a syringe. This tube must be kept sterile for convenience in cross matching throughout the 21 day storage period. The others serve for serology, Rh typing, routine grouping, and cross-matching. The needle is then removed from the vein and the donor is instructed to apply pressure to a sponge placed over the site of puncture. This must be done with arm elevated to the vertical position to minimize venous pressure. The traditional flexion of the elbow should be discouraged because it results in a high incidence of ecchymosis about the antecubital fossa because the high venous pressure which results from the muscular contraction during forced flexion pumps blood out of the vein into the subcutaneous tissues. The glass collecting tube is next removed from the rubber bushing. Because the end of this tube is relatively small, there is little danger of wetting the lumen of the bushing with blood, figure 224, 6, if excess blood has been removed on the stainless steel tube as described above. The sterile stainless steel stopper is reinserted, figure 224, 7. A tag, figure 226, 1, is hung around the neck of the flask, the pilot tubes are slipped through the holes in the tag so that the blood record and pilot tubes are essentially a single unit, figure 224, 8, and the unit is taken to the blood laboratory, where the blood is typed immediately and serology performed.

If an emergency transfusion is contemplated the blood can be infused from the same container in which it was collected merely by removing the stainless steel stopper and inserting in its place the combined air vent and stainless steel filter as described below.

If the blood is to be stored it is centrifuged for forty five minutes at 1500 times gravity while still warm and then cooled to 4° to 10°C where it is maintained until

used. Variations in temperature cause rapid destruction of erythrocytes, hence storage temperature is more important than the actual level maintained. Experience has shown that the period of storage which yields optimum results for both whole blood transfusions and plasma production is twenty-four days. Storage at temperatures above 10°C results in rapid deterioration. Below 4°C fibrin precipitation is excessive.

VACUUM TECHNIC

A special container for collecting blood and a collection kit are necessary for the vacuum technic.

Solution Required

Freshly prepared ACD solution (125 cc) is sterilized in a centrifuge bottle fitted with a rubber bushing and a special stainless steel stopper. This stopper, figure 227, differs from the stopper used for glass collection in that there is an axial hole through the stem and a nipple on the other end of the stem. A small rubber diaphragm, figure 227, 1, fits the nipple snugly and provides a hermetic seal when the stem of the stopper is completely inserted in the bushing, figure 227, 3. The rubber diaphragm in turn is bacteriologically protected by a small metal cap which is mounted and applied prior to sterilization. During sterilization the stem of the stainless steel stopper is positioned so that all the air can be expelled from the container through the channel in the side of the stopper. When sterilization is complete, the stainless steel stopper is pushed home. As the container cools, at least a 20 mm Hg vacuum is formed. This vacuum can be used to aid in the aspiration of blood through a small needle inserted into the vein of the donor.

VACUUM TECHNIC FOR BLEEDING

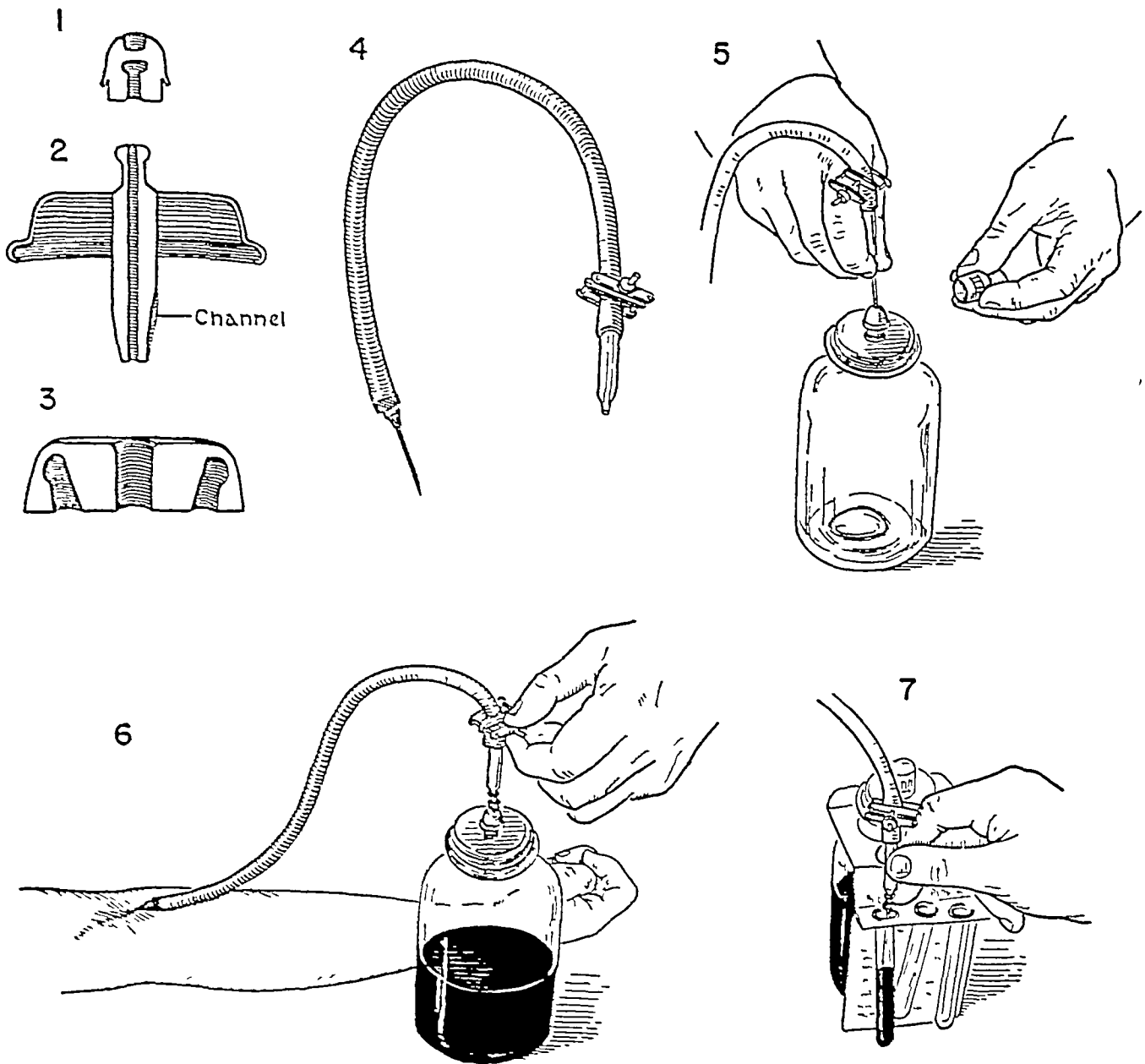


FIGURE 227

Apparatus Required

The vacuum blood collection kit contains pressure tubing 45 cm long (4.5 mm. bore \times 2 mm. wall) fitted with a needle adaptor and a No. 16 gage needle, one Hoffman type clamp, a needle holder containing a 4 cm No. 19 gage intravenous needle, and three test tubes (13 \times 100 mm) with corks. This equipment is assembled as illustrated in figure 227. 4

The donor is prepared as outlined. The vacuum technic deviates at the point where the blood collecting container is readied for use. The sterile collecting kit is extruded from its envelope and the protecting metal cap is removed from the rubber diaphragm, figure 227. 5, and placed carefully in a sterile corner of the tray. The cotton plug is removed from the needle holder and the No. 16 gage needle is attached to the adaptor. The

CENTRIFUGING BLOOD

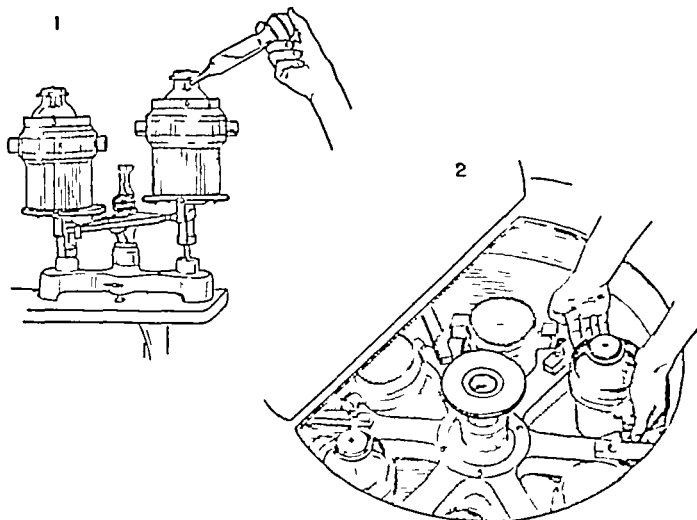


FIGURE 228

Hoffman clamp is applied to the rubber tubing as near to the piercing needle as possible. After the clamp has been closed firmly, the piercing needle is thrust through the center of the rubber diaphragm, figure 227, 5. The cotton plug is then removed from the opposite end of the needle holder and a No. 19 gage venipuncture needle is attached to the adaptor. Venipuncture is performed and the Hoffman clamp is slowly opened, figure 227, 6. The blood is aspirated through the small needle directly into the ACD solution. Care must be taken to maintain sufficient venous pressure so that the vein is distended at all times. If the flow is not adequate, the fault usually lies at the tip of the venipuncture needle. If

too much vacuum is applied, the wall of the vein is often caught across the lumen of the cannula and the flow of blood stopped. When the desired amount of blood has been withdrawn, the clamps are removed from the sphygmomanometer cuff and the donor relaxes his arm. The piercing needle is removed from the diaphragm and blood is collected for serology and typing determinations, figure 227, 7. The phlebotomy needle is then removed. The small metal cap is reapplied to protect the rubber diaphragm. The pilot tubes are inserted into the properly folded tag and the latter is fixed about the neck of the container as illustrated in figure 227, 7.

If the vacuum in the container is lost

VACUUM TECHNIC FOR BLEEDING

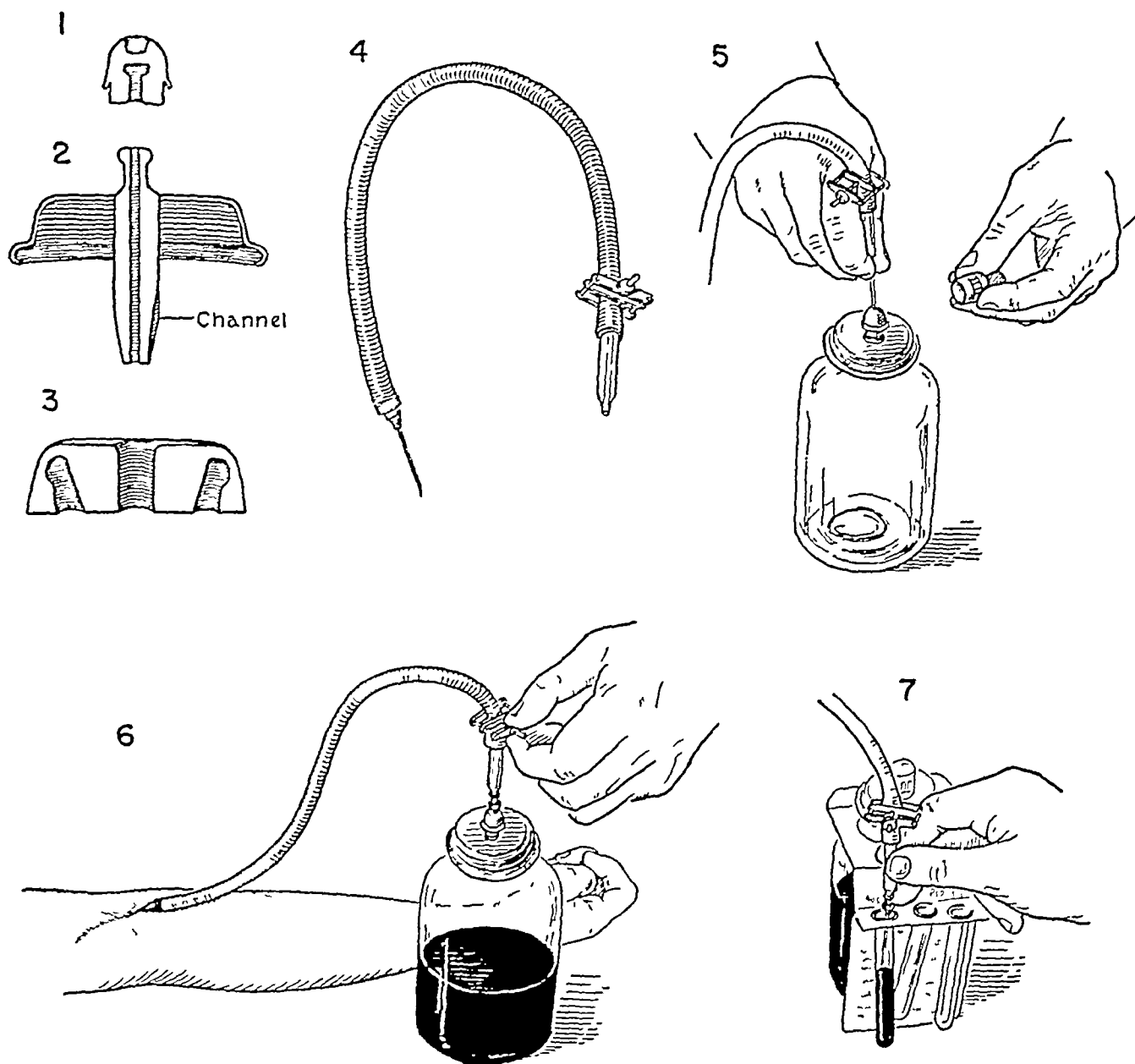


FIGURE 227

Apparatus Required

The vacuum blood collection kit contains pressure tubing 45 cm long (4.5 mm. bore \times 2 mm. wall) fitted with a needle adaptor and a No 16 gage needle, one Hoffman type clamp, a needle holder containing a 4 cm No 19 gage intravenous needle, and three test tubes (13 \times 100 mm) with corks. This equipment is assembled as illustrated in figure 227, 4.

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CENTRIFUGING BLOOD

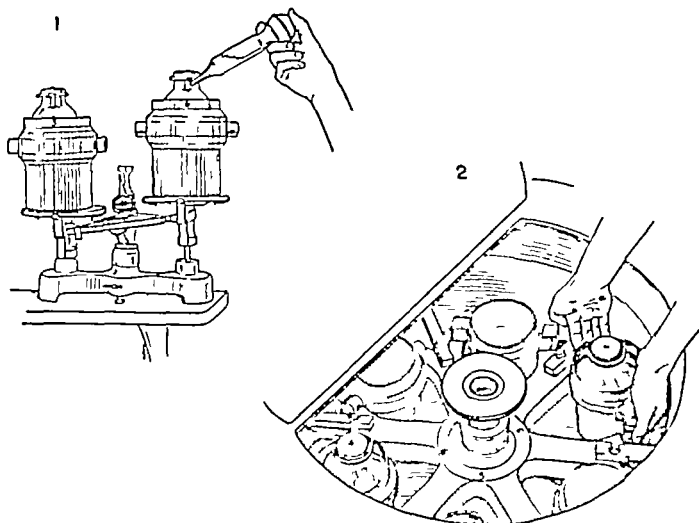


FIGURE 228

Hoffman clamp is applied to the rubber tubing as near to the piercing needle as possible. After the clamp has been closed firmly, the piercing needle is thrust through the center of the rubber diaphragm, figure 227, 5. The cotton plug is then removed from the opposite end of the needle holder and a No. 19 gage venipuncture needle is attached to the adaptor. Venipuncture is performed and the Hoffman clamp is slowly opened, figure 227, 6. The blood is aspirated through the small needle directly into the ACD solution. Care must be taken to maintain sufficient venous pressure so that the vein is distended at all times. If the flow is not adequate, the fault usually lies at the tip of the venipuncture needle. If

too much vacuum is applied, the wall of the vein is often caught across the lumen of the cannula and the flow of blood stopped. When the desired amount of blood has been withdrawn, the clamps are removed from the sphygmomanometer cuff and the donor relaxes his arm. The piercing needle is removed from the diaphragm and blood is collected for serology and typing determinations, figure 227, 7. The phlebotomy needle is then removed. The small metal cap is reapplied to protect the rubber diaphragm. The pilot tubes are inserted into the properly folded tag and the latter is fixed about the neck of the container, as illustrated in figure 227, 7.

If the vacuum in the container is lost

through faulty manipulation, the flow of blood can be continued by wiggling the stainless steel stopper out of the bushing sufficiently so that the channel serves as a vent

CENTRIFUGING

The operation of the centrifuge is not difficult if the purpose of the operation is kept in mind. Centrifugal force acts selectively on the constituents suspended in blood and sorts them out according to their relative densities, the heavier tending to layer out at the periphery of the spinning container. In the centrifuges used in blood laboratories, the bottles are spun in a horizontal position and the red cells tend to pack together in the bottom of the bottles. For successful centrifuging, the speed of the centrifuge must be sufficiently great to effect a clean separation of the red cells from the plasma. A force of 1500 times gravity exerted for forty-five minutes is sufficient to do this.

Vibration militates against successful centrifuging because it stirs up the packed red cells or prevents the development of sufficient centrifugal force to cause a separation of the cells. In a properly constructed centrifuge, the difficulties encountered are all due to careless operation.

The most important step in the operation of a centrifuge is proper loading. This is done by removing diametrically opposite trunnion cups from the centrifuge, inserting the bottles of blood in the cups and balancing them against each other on a torsion balance. The steps in balancing follow:

- 1 The empty balance is adjusted so that the pointer swings an equal distance on either side of the zero point.

- 2 The paired trunnion cups are placed on either balance pan and 10 cc of water are put in each cup.

3. Centrifuge bottles containing approximately equal volumes of blood are placed in the trunnion cups.

- 4 The trunnion cups are carefully balanced by adding water to the lighter cup by means of an Asepto syringe, figure 228, 1.

- 5 When the cups have been carefully balanced and the pointer swings an equal number of divisions on either side of the zero point of the scale, the trunnion cups are removed and hung in the proper pockets of the centrifuge head. Carelessness at this stage is a frequent cause for vibration. The number one trunnion cup must always be hung in the number one pocket, and so on, figure 228, 2.

- 6 The windshield cover is replaced and screwed down snugly.

- 7 The centrifuge cover is closed and locked.

- 8 The centrifuge is started slowly by turning up the rheostat step by step. If unusual vibration occurs, the centrifuge is stopped immediately and inspected to be certain that the trunnion cups are in their proper position. If they are properly located, the cause of the vibration must be sought in improper balance and all the cups should be rebalanced.

9. The centrifuge is run forty-five minutes at 1500 times gravity. The speed at which an individual centrifuge must be run to attain this centrifugal force varies with the diameter of the centrifuge head. The following table correlates the diameter of the head and the speed necessary to develop 1500 times gravity. When a speed of 2000 R P M cannot be exceeded, the period must be prolonged sufficiently to attain good separation.

- 10 After the period for centrifuging has elapsed, the switch is turned off and the centrifuge is allowed to run down. The brake must not be applied because sudden

SIZE OF BOTTLES	ROTATING RADIUS BOTTOM OF BOTTLE	SPEED REVOLUTIONS PER MINUTE	RELATIVE CENTRIFUGAL FORCE AT BOTTOM OF BOTTLE
600 ml.	28.5 cm.	2170	1500 × G
600 ml.	25.0 cm.	2310	1500 × G
300 ml.	23.8 cm.	(not safe) 2370	1500 × G
300 ml.	19.0 cm.	(not safe) 2670	1500 × G

change in speed will stir up the packed red cells

11 When the centrifuge has stopped, unlock the cover, unscrew the windshield cover, and remove the centrifuge bottles from the trunnion cups. With well packed cells, only ordinary care is necessary to prevent disturbing the cells. If the bottles containing the centrifuged blood are placed in the refrigerator for several hours, the red cells tend to "jell" and aspiration of the plasma is easier

ADMINISTRATION

The first step in infusing blood is to check the tag to be absolutely certain that the blood is compatible with that of the proposed recipient. Usually the blood is given cold but it may be heated to 37°C if the patient is in shock or in critical condition. This is readily done by exposing it to an environment no hotter than 37°C for thirty minutes before it is infused. A water bath or an electric heater is suitable, figure 230, 4

If the whole blood is to be used, the centrifuge bottle is thoroughly shaken to mix the cells and plasma. Only blood showing no hemolysis should be infused. Because small clots of fibrin form in approximately 10% of the containers of stored blood, inconvenience can be avoided by filtering the blood before administration. This can most easily be done in the laboratory by inserting the stainless steel filter assembly illustrated in figure 229, 2, inverting the flask and collecting the blood in a

sterile container, figure 229, 4. Suction can be used to assist the filtration should it slow down. The second container is stoppered by reinserting the sterile stainless steel stopper.

To infuse the blood, the stainless steel stopper is rocked and twisted out of the bushing. A sterile recipient set is extruded from the sterilizing envelope and the vent tube is inserted into the orifice of the rubber bushing until the two circumferential beads on the glass portion of the tube embrace the rubber bushing, figure 229, 3. The flask is inverted, figure 229, 5, the air is displaced from the filter and tubing, and venipuncture is performed. The doctor must stand by while the blood is infused to detect signs or symptoms of any untoward reaction. When blood must be infused rapidly, a 14 gage needle should be selected. In an exsanguination emergency the blood can be pumped into the recipient by inserting a transfusion pump into the line. After the infusion has been completed, the equipment is returned to the blood laboratory immediately where it is thoroughly rinsed with cold water.

PLASMA PRODUCTION

If the centrifuged blood is not used as whole blood within a 21-day period, it is advantageously converted to plasma as the end product of the blood bank. The clear, supernatant plasma is aspirated from the individual collecting containers into a large pooling flask where it is mixed with the plasma from other donors to reduce the titer of whatever agglutinins may be present. The plasma from at least eight donors should be pooled so that statistically all the agglutinins are likely to be represented. Because of the hazard of infecting recipients with homologous serum jaundice, the history of all donors contributing to a plasma pool must be reviewed critically to exclude any who have had jaundice or have

FILTERING BLOOD

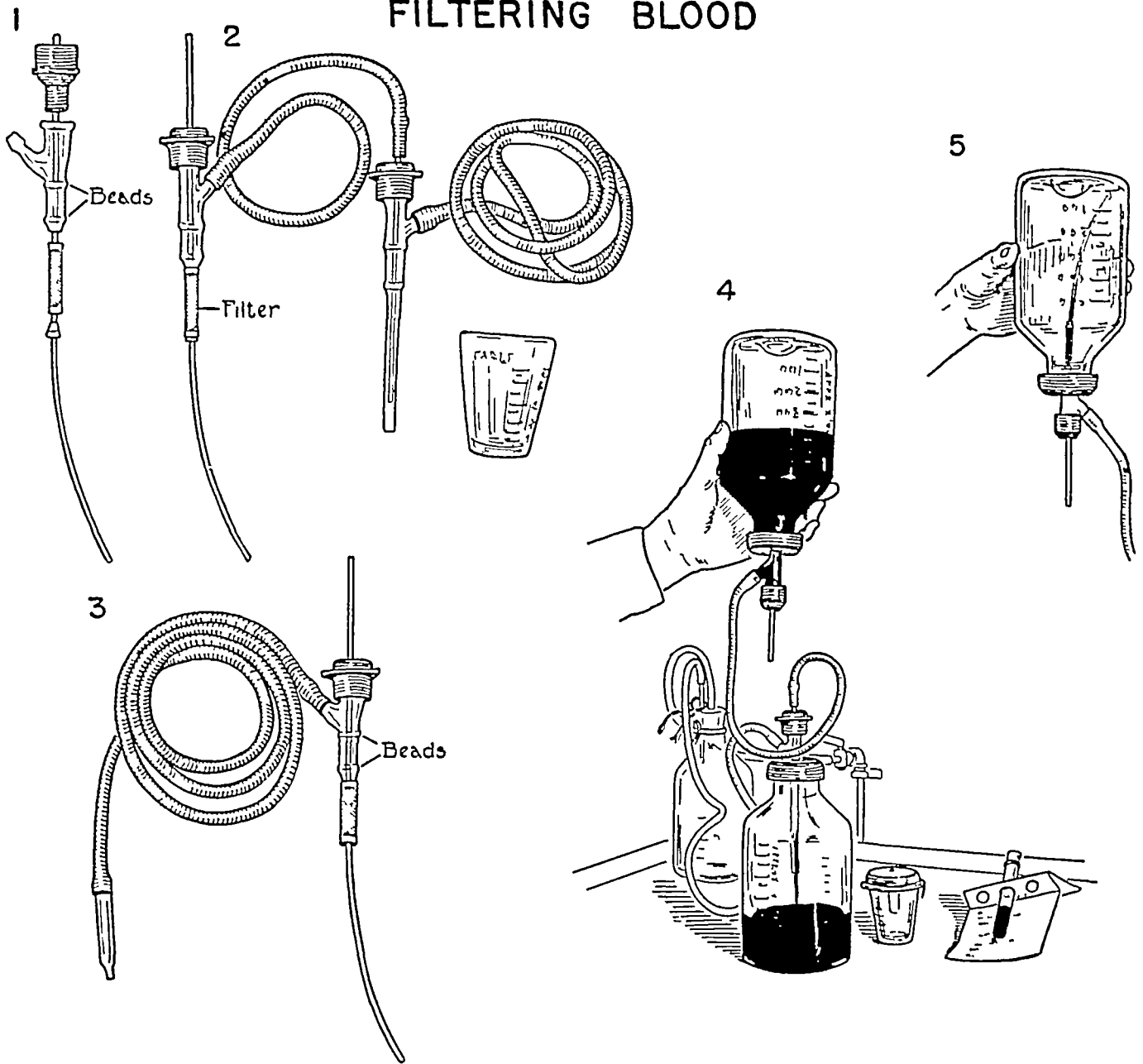


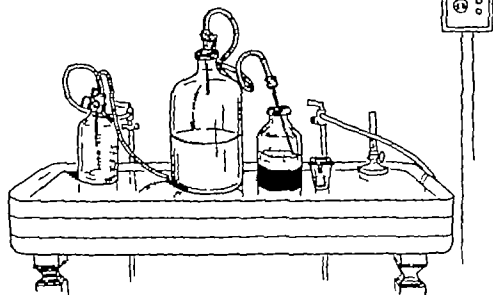
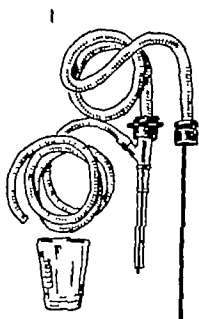
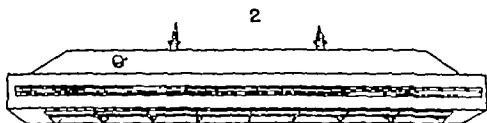
FIGURE 229

been associated with jaundiced persons. To date there is no laboratory method for determining the safety of plasma in this regard. Only plasma with a negative serologic test for syphilis should be used.

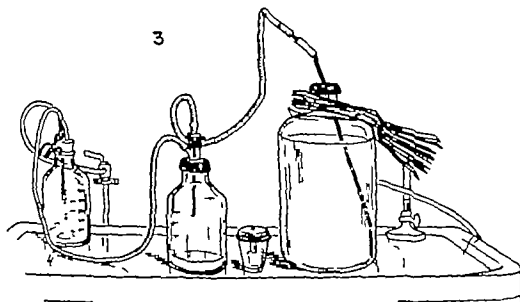
The procedure can be performed under ultraviolet radiation with little danger of contamination, figure 230, 2. If aseptic technic is maintained, plasma can be added to the pooling flask periodically until it is full. An aspirating tube, figure 230, 1, is

substituted for the stainless steel stopper in the pooling flask and its side arm attached to a source of vacuum maintained at a negative pressure of 12 cm of water. The slender glass tube is then inserted through the hole in the bushing of the collecting bottle and the clear plasma is drawn off. If the container is held at the eye level, all but 10 or 15 cc of the plasma can be removed without stirring up red cells or the "buffy coat" which overlies them.

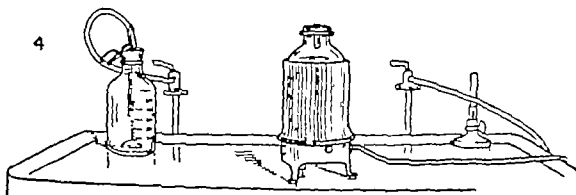
POOLING AND BOTTLING PLASMA



3



4



The bookkeeping on the plasma pool is readily taken care of simply by accumulating the tags from the collecting bottles on the neck of the pooling flask, figure 230, 3

When the pooling flask is full, it should be allowed to stand at room temperature for twenty-four hours and must be cultured prior to the addition of preservatives. The technic of choice for culturing pooled plasma is that recommended by the National Institute of Health ⁷

TESTS FOR STERILITY

Tests for sterility are required on the plasma before the addition of the preservative. At this point the tests may be made on the plasma from the individual bleedings or on a sample taken from the plasma pool prior to the addition of the preservative. Sterility tests are also required on the finished product as contained in the finished dispensing unit

Test Culture Medium

The National Institute of Health has adopted as the standard culture medium for making the sterility test on all biologics under its control a medium designated as "Fluid Thioglycollate Medium"

FLUID THIOGLYCOLLATE MEDIUM (LINDEN)

	Grams
Peptone	20.0
Dextrose (anhydrous)	5.0
Yeast extract	2.0
Sodium thioglycollate	1.0
Sodium chloride	5.0
Agar (less than 15% moisture by weight)	0.5
Dipotassium phosphate (K ₂ HPO ₄)	2.5
Distilled water	1000.0 cc
0.2% solution of methylene blue (cert.)	1.0 cc

Dissolve the agar in half the volume of distilled water by boiling or heating in the Arnold. Dissolve the remaining ingredients, except the

methylene blue, in the remaining water with the aid of heat. Now mix the two portions, adjust the reaction with sodium hydroxide to such a point as experience shows will result in a pH of 7.5-0.1, in the completed and sterilized medium. Filter clear while hot and add the methylene blue solution. Distribute into final containers of the desired size and sterilize in the autoclave for 18 to 20 minutes at 15 to 17 pounds pressure (121° to 123°C)

A medium may be prepared as a premixed dehydrated stock of the essential ingredients contained in Method B formula. Such premixed stock is now being commercially prepared and this has proved equally satisfactory and has the advantage of being certified as to growth qualities. Directions for preparation are given on the label.

At the end of the incubation period used for the sterility test less than 50% of the medium in each tube shall have changed from the color of the fresh medium to a green color.

Sterility Test on the Pool

When this method of testing for sterility is selected, the procedure shall be as follows. For liquid or frozen plasma two separate samples shall be withdrawn from the well mixed pool for the sterility test. The size of each sample shall be not less than 20 cc. for each liter of plasma in the pool under test. For the sterility test the entire volume of one of the two samples shall be planted in one or more portions of thioglycollate medium. If evidence of contamination appears the test shall be repeated with the second sample and if this test also shows the presence of contamination the pool shall be discarded.

After the cultures on the plasma pool are reported negative, the quarantine is lifted and the plasma is bottled into individual containers of 500 cc. each. This is conveniently done by using the same type apparatus which was used to pool the plasma, the aspirating tube being substituted for the stainless steel stopper in flasks containing 50 cc. of 50% dextrose solution,

⁷ Bulletin: Unfiltered Normal Human Plasma, National Institute of Health, Bethesda, Maryland, 3rd rev., August 15, 1942

figure 230, 3 The dextrose is added to prevent the formation of precipitate when the plasma is allowed to stand for prolonged intervals at room temperature. Bottles full of plasma are sealed by reinserting the stainless steel stopper. A tag, such as illustrated in figure 226, 2, is fixed to the neck and the plasma is frozen in a cabinet held at -23°C . Frozen plasma can be stored indefinitely in a suitable refrigerator

To use frozen plasma, it is thawed by heating it as shown in figure 230, 4, in an environment of 37°C until the ice is melted. It is then thoroughly shaken. A filter assembly, figure 229, 3, is inserted in place of the stainless steel stopper, the flask is inverted, figure 229, 5, and the infusion is begun. Plasma that has been properly prepared and sealed can be melted and stored as a liquid for months without deterioration.

CHAPTER XVIII

CENTRAL SUPPLY ROOM TECHNIC

The dust factor alone should always point a warning finger at us before guests are invited into the operating room. The spectator exerts another influence upon the surgeon which he secretly feels and openly denies. Idiomatically he is "on the spot." A surgeon is as human as any one else and seldom can be expected to do his best work under pressure of a critical audience.

—JEAN M. STEVENSON AND MONT R. REID, 1941¹

A central supply room has proved as essential in hospital organization as a tool crib in a machine shop. But two functions of the toolroom make it indispensable. One is the control of the inventory of tools so that loss and waste are eliminated, and the other is the provision of experts to maintain the tools in standard usable condition. Both points are a crying need in most hospitals and the central supply room offers the only economical solution. Besides these major advantages, there are many other benefits. Advantage can be taken of a division of labor which is impossible in individual departments or wards of the hospital. Lay help can be trained to do many of the tasks in a supply room more efficiently and inexpensively than when nurses are depended upon. Wide experience has shown, for example, that an intelligent, habitually neat and clean girl with a high school education can make up all the parenteral fluids and the equipment for their administration with a minimum of supervision. Such persons accept the job as a challenge and look upon it as a worth-while career whereas most

nurses feel that it is a menial chore which is not worthy of their interest. When properly organized, a central supply room can be a valuable classroom for student nurses because the hospital can well afford an expert supervisor who has the knowledge and skill to discharge her responsibility well. These attributes are essential for teaching student nurses a reliable technic based upon actual facts rather than upon tradition and improvised technic. Duplication of equipment can be minimized and conservation of supplies and apparatus and instruments can be encouraged. The final outstanding advantage accrues to the hospital as a whole because all types of supplies and equipment are ready for instant use and if the central supply room is worthy of the name, every item which is issued from it will be in usable condition and packaged in a standard manner.

If the concept of a central supply room is sound, there should be no difficulty in deciding that as many functions as possible should be assigned to it. Many hospitals have failed to recognize this and maintain, in fact, overlapping organizations to carry on functions which should be delegated to but one. Effective control of inventory or standards of quality is impossible when

¹ STEVENSON, J. M. and REID, M. R. *Operative Surgery*, edited by F. W. BANCROFT. New York, D. Appleton-Century Company, Inc., 1941, p. 243. New Edition to be published by J. B. Lippincott Company.

more than one organization is charged with the same duties. The minimum duties which should be assigned to a central supply room are indicated in figure 231, which also indicates a division of labor that will be found most effective from a point of view of smooth function of the supply room and coordination of its efforts with those departments of the hospital with which it has its chief contact.

The physical layout need not be elaborate. A plan as shown in figure 232 provides adequate facilities for a hospital of 250 beds. Notable features are the elimination of fixed equipment and the substitution of various kinds of tables designed to facilitate the work. These tables are fitted with large casters so that they can be pushed out of the way when other functions are being performed. Emphasis should be placed upon adequate lighting and ventilation. The latter is noteworthy lacking in most hospital supply rooms. A complete change of air fifteen times per hour is not excessive for comfortable working conditions in a central supply room.

Many central supply rooms assume the responsibility for the manufacture of sponges, etc. Experience has convinced the author that machine made supplies are usually less expensive and possess standard quality which is unattainable when these supplies are made by hand. This is only true, however, when the needs are anticipated and supplies are purchased in the most advantageous quantities.

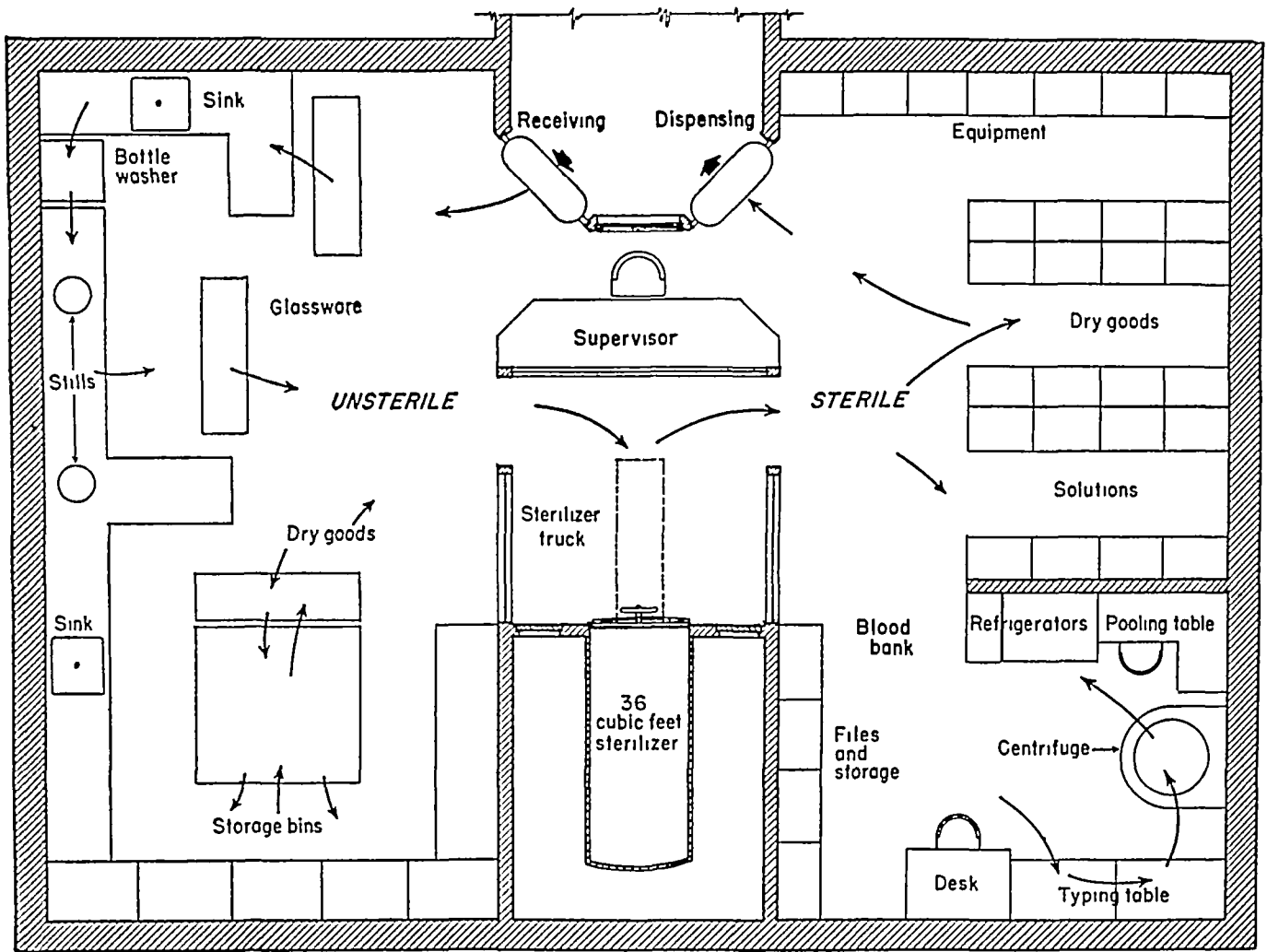
The type of technic to be used in the central supply room is well illustrated by the material presented in Chapters X, XI, XVI, and XVII and need not be elaborated upon further. Figure 233 illustrates a dressing kit, a catheterization kit, and a lumbar puncture kit which are useful. The most important feature of the small kits is the sterilizing envelope, figure 209, 5

which not only provides protection for the sterile contents but also is a convenient means for returning the used equipment to the supply room. This is important because it prevents loss and breakage of equipment by making it so easy to gather together the contents of each kit for return to the supply room that they are not accumulated on the ward and returned in large batches where breakage and loss are frequent.

Figure 234 illustrates a kit which has been assembled to provide all the necessary equipment to administer oxygen through a B.L.B. mask. When this kit leaves the central supply room, it is in a true sense emergency equipment in that it can be applied to the patient without the hectic rush for tools and sundry small parts which so often attends the use of emergency equipment when not kept in usable condition. When the mask is returned to the central supply room, it is carefully disassembled and thoroughly washed with a solution of 1:1000 sodium hypochlorite and rinsed in tap water. The exhaling/inhaling valve is held in a turret molded into the down tube of the mask, figure 234, 4. The valve proper consists of a disc of fine-grain sponge rubber. This disc slips into the turret and is retained by the outer flange of the turret. It is readily removed by squeezing the sides of the turret and lifting it out with the thumb and forefinger. To clean the disc, it is saturated with hypochlorite solution several times. It is then thoroughly rinsed in clear water and squeezed dry.

Familiarity with the function of the various parts of the mask insures intelligent care. The oxygen enters the mask through the inlet tube which delivers it at the lower end of the reservoir rebreathing bag. The patient inhales the contents of this bag through the down tube and if the bag is completely emptied, atmospheric air enters through the sponge-rubber valve to permit

FLOOR PLAN OF CENTRAL SUPPLY ROOM



Markus & Nocka

FIGURE 232

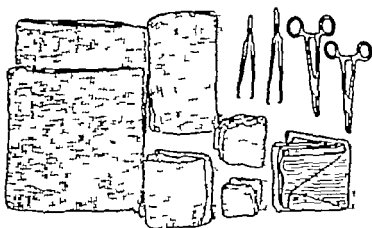
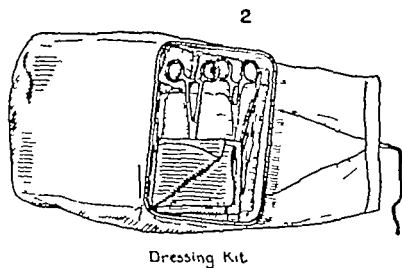
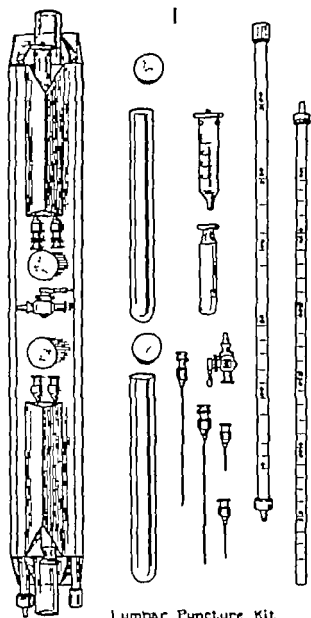
complete inspiration. The gases exhaled initially (tidal air) pass through the down tube and into the bag and are available for rebreathing. After it becomes distended with the mixture of expired air and fresh oxygen, the pressure in the down tube is increased slightly and the rest of the exhaled air is forced out the exhaling valve. This portion of the expiration is chiefly alveolar air and contains most carbon dioxide. Sufficient moisture accumulates in the rebreathing bag from expirations to humidify the fresh oxygen.

After the mask has been reassembled, the reducing valves and flow meter are then

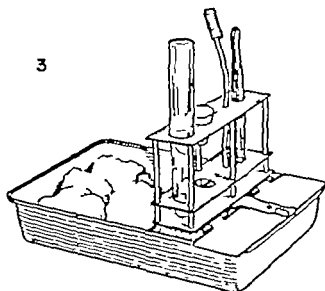
attached to an oxygen cylinder and the mask tested by applying it to the back of the hand so that faulty assembly or leaky parts are evident. Sodium hypochlorite is the best cleansing agent because it disinfects and deodorizes the rubber and also dissolves any mucus which has adhered to the inside of the mask.

Proctoscopes, sigmoidoscopes, and similar equipment are carefully disassembled as soon as returned. The battery, light cord, and light carrier are separated from the remainder of the equipment which is thoroughly scrubbed in 1:1000 solution of sodium hypochlorite and rinsed in tap

STANDARDIZED KITS FOR WARD USE



3

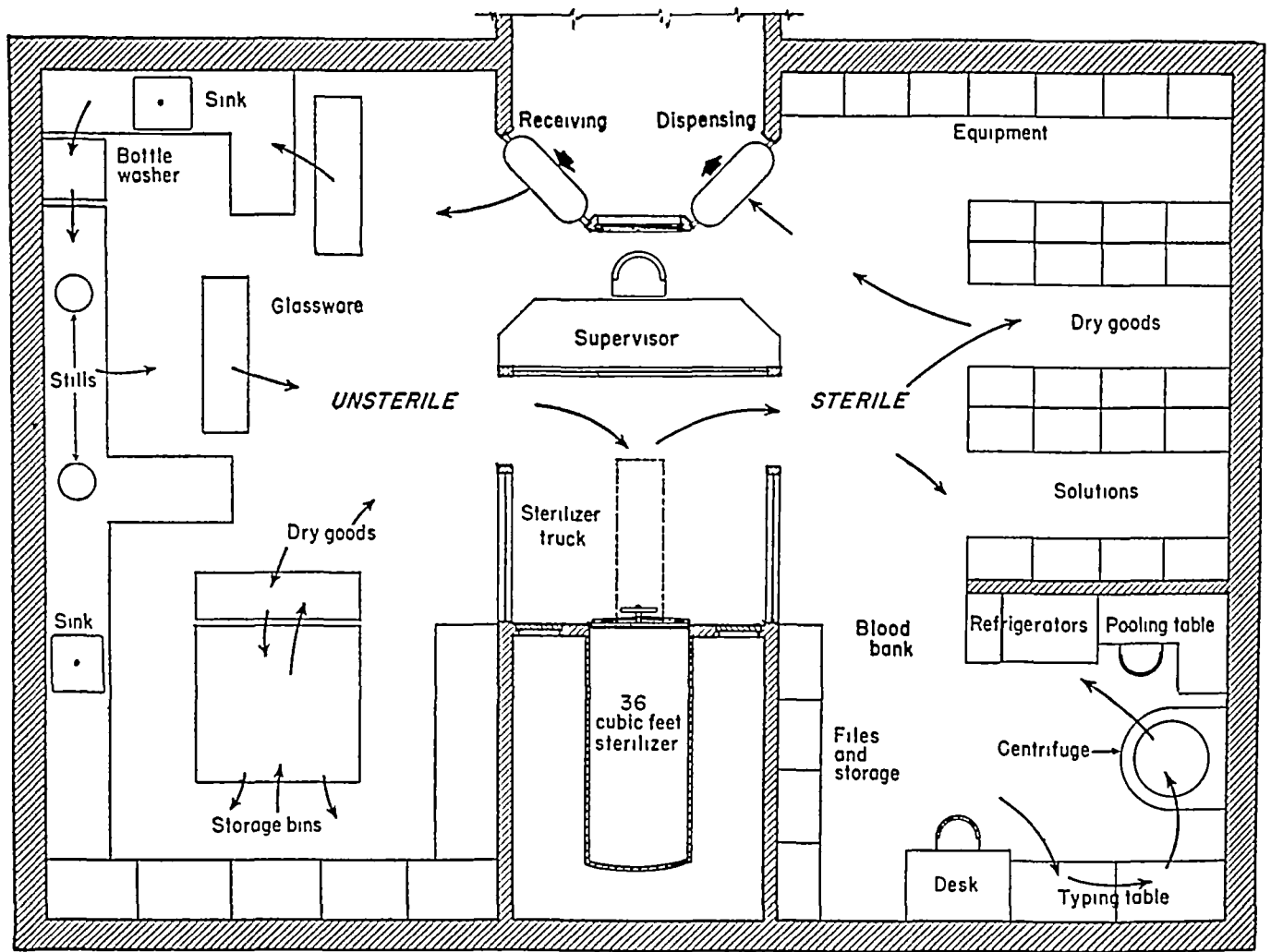


Catheterization Kit

FIGURE 233

[329]

FLOOR PLAN OF CENTRAL SUPPLY ROOM



Markus & Nocka

FIGURE 232

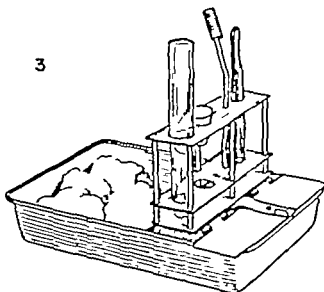
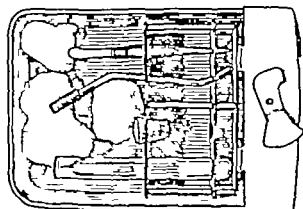
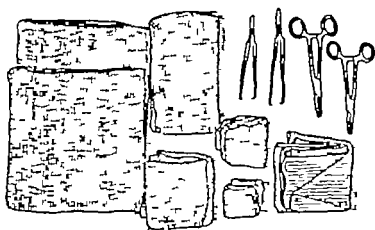
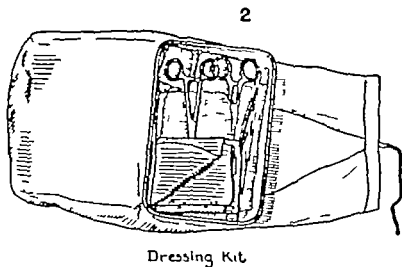
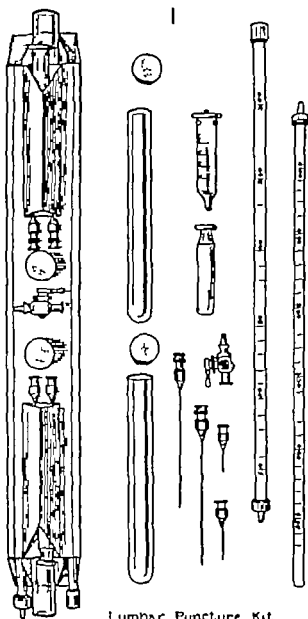
complete inspiration. The gases exhaled initially (tidal air) pass through the down tube and into the bag and are available for rebreathing. After it becomes distended with the mixture of expired air and fresh oxygen, the pressure in the down tube is increased slightly and the rest of the exhaled air is forced out the exhaling valve. This portion of the expiration is chiefly alveolar air and contains most carbon dioxide. Sufficient moisture accumulates in the rebreathing bag from expirations to humidify the fresh oxygen.

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Proctoscopes, sigmoidoscopes, and similar equipment are carefully disassembled as soon as returned. The battery, light cord, and light carrier are separated from the remainder of the equipment which is thoroughly scrubbed in 1:1000 solution of sodium hypochlorite and rinsed in tap

STANDARDIZED KITS FOR WARD USE



Catheterization Kit

FIGURE 233

[329]

KIT FOR OXYGEN THERAPY

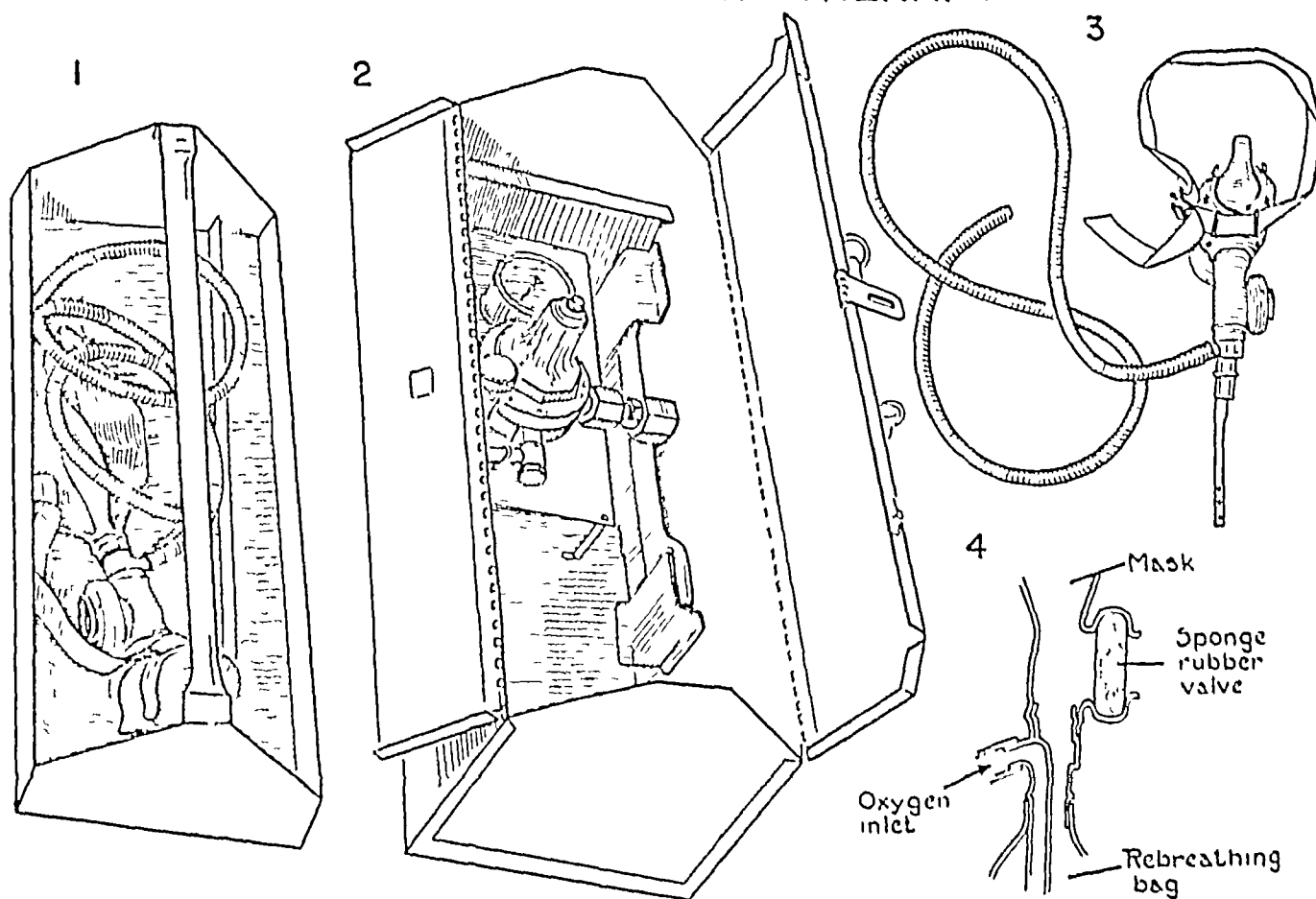


FIGURE 234

water. It is carefully dried and a long pipe cleaner is run through the tunnel provided for the light carrier. The end of this cleaner should be doubled back on itself so that the wire will not scratch the light hood. When the cleaner has impinged against the glass, it should be rotated several times so that the inner surface of the glass is wiped clean. The various parts of the proctoscope are then assembled, the light carrier is cleansed, without removing the lamp, by rubbing it with a cloth moistened in sodium hypochlorite. Care must be taken not to squeeze moisture into the joint where the lamp screws into the carrier or into the connector at its other end. The rubber cord is wiped

with the same moistened cloth. The rheostat is then turned to zero and the carrier, cord, and battery connected. The light switch is then turned to the "on" position and the rheostat is gradually turned up until the filament in the lamp glows. Care should be taken not to turn the current any higher than the point where the U-shaped filament is seen as a single source of light rather than a U-shaped light. The rheostat is then turned back to zero and the carrier disconnected from the cord. The set is arranged in a sandwich bread pan with a sliding cover and the tag initialed so that the person who checked and tested it can be identified at a later date.

HOSPITAL INFECTION OF WOUNDS

It is, unfortunately, a melancholy story that ever since surgery began, the most of the mischief was done by the surgeon himself. It was the willing and tender, though unclean hand, that carried the poison into the wounds. It is to this that Lister has put a stop. With a proper antiseptic, an operator is now made to be clean in spite of himself, is compelled to have safe sponges, safe ligatures, clean instruments, and, above all, clean fingers

— THOMAS KERRI, 1885¹

A startling contribution to the welfare of surgical patients has come from surveys made in England and Australia on those injured in World War II^{2, 3, 4, 5, 6, 7}. Careful studies show that the majority of fresh wounds are not infected with virulent pathogenic bacteria when the victims reach the hospital. The wounds show contamination with pyogenic organisms for the first time shortly after the first routine dressing. Detailed investigation of droplet infection and dust distribution in wards, dressing technic, and related factors was startling. The primary cause of hospital wound infec-

tion is the mechanical transfer of pyogenic organisms from infected wounds to clean ones by the hospital personnel during routine dressings. Secondary infection occurred in only 5% of open wounds on admission to the hospital, in 50% after one week's stay and from 70% to 80% as hospitalization progressed⁸. This point has been emphasized repeatedly by traumatic surgeons as well as by those who have mastered the care of septic hands. Droplet and dust borne infections were demonstrated to be secondary factors. Intelligent revision of dressing technic resulted in a decrease in the infection of traumatic wounds from 30% to 2.2% and in clean wounds from 5% to zero.

Control of hospital infection is not difficult but it depends upon the sincere cooperation of everyone coming in contact with patients who have unhealed wounds. It does little good for nine tenths of the staff to carry out an ideal technic when one tenth is careless or when teaching rounds create hysteria and dressing after dressing is taken down without adequate precautions. Like aseptic technic in the operating room, a technic for the prevention of the spread of disease on hospital wards must be well organized and

¹ KERRI, THOMAS. *Contributions to the Surgical Treatment of Tumors of the Abdomen. Part I. Hysterectomy for fibrous tumors of the uterus*. Edinburgh: Oliver and Boyd, 1885.

² MILES, A. A., SCHWABACHER, H., CONLIFFE, A. C., ROM, J. P., SPOONER, E. T. C., PILCHER, R. S. and WRIGHT, J.: Hospital Infection of War Wounds, *Brit. M. J.*, 2:1855 1940.

³ McKIMOCK, W., WRIGHT, J. and MILES, A. A.: The Reduction of Hospital Infection of Wounds: Controlled Experiment, *Brit. M. J.*, 2:375 1941.

⁴ STEPHEN, R. L.: Hospital Infection of Wounds, *Med. J. Australia* 1:124 1944.

⁵ KINSELLA, V. J.: The Prevention of Hospital Infection of Wounds, *Med. J. Australia*, 1:121 1944.

⁶ WITTE, C.: The Prevention of Hospital Infection of Wounds, *Med. J. Australia*, 1:126 1944.

⁷ SHOOTER, R. A. and WATERWORTH, P.: Transmissibility of Hemolytic Streptococcal Infection by Fleas, *Brit. M. J.*, 1:247 1944.

⁸ Editorial. *The Ward Dressing Level* 2:565 1941.

drilled into the staff through constant example

From the discussion on disinfection of the skin, it is obvious that a careful surgeon protects his hands against contamination at all times. The surgeon's selfish interest in the safety of his own hands and the well-being of the patients upon whom he is to operate can only be protected by the utmost care in doing dressings. A "no touch" or instrument technic should be used because it has been demonstrated that the outside layer of a dressing frequently harbors organisms which have soaked through or have grown into a moist dressing.

When fingers are inadvertently contaminated, they should be disinfected immediately by gently rinsing off the septic material and applying an effective germicide (Chapter XII). Those with infected lesions of the hand should refrain from doing dressings because the same factors which make a patient's dressing dangerous to the surgeon operate in reverse.

Droplet infection can be controlled only by masking those present at the dressing, including the patient himself, unless the dressing team and the patient can be disciplined sufficiently well so that talking, laughing, sneezing, or sighing are eliminated. Because no mask yet devised is effective, persons with colds should no more attempt to do a dressing than they should serve on an operating team.⁹

To protect the patient with multiple wounds against cross contamination from one wound to another, only one dressing should be done at a time, even though the wounds may seem to have a common origin and obviously a common host.

It is interesting that bandage scissors were indicted as the conveyor of organisms from one wound to another, yet even in

modern hospitals any nurse or intern will brandish his bandage scissors at a second's notice. Cast cutters also carry infection from patient to patient. These instruments must be sterilized every time they are used just as are the forceps that are used in the actual dressing.

Unsuspected sources of gross contamination should be controlled. The push plates, elbow hooks, and knobs of doors and faucet levers are often carelessly contaminated, as are hand brushes. The latter cause for wound infection was strikingly demonstrated as early as 1891.¹⁰

The control of dust is the most difficult problem of all because the sources of dust are ubiquitous and cleansing methods are grossly inadequate. The only satisfactory method of ridding a room of dust is to use a vacuum cleaner of the type which expels the exhaust air to the outside atmosphere. Other vacuum cleaners simply remove gross dust from the air and redistribute the fine dust about the room. Because few hospitals have adequate vacuum cleaning systems, it is important to arrange the time for doing dressings at least thirty minutes after the beds have been made, the floors have been swept, and patients or their visitors have been moving about to permit bacteria to disappear from the air as shown in figure 134. Windows should be closed prior to doing dressings for the same reason. Oiled floors and treated textiles are essential aids in controlling dust as is presented in Chapter XIII.

Other overlooked but obvious causes of gross contamination are wash basins and bed pans, which must be sterilized either following every use or kept for individual use only. The transfer of bed clothing, particularly the outer blanket from one bed to another without disinfection, is a gross breach in technic which is carefully per-

⁹ Editorial. The Individual Streptococcus Carrier, *JAMA*, 125:556, 1944.

¹⁰ SCHIMMELBUSCH, C. *The Aseptic Treatment of Wounds*. London: H. K. Lewis, 1894.

formed in the best hospitals each night and morning. The proper disposition of soiled linen, as outlined in Chapter XV, is too often overlooked. The indiscriminate passing of books and papers between wounded, surgical as well as traumatic, patients should not be permitted.

This discussion will probably prompt the feeling in most readers that a proper technic for dressing wounds is just as elaborate as that necessary to control communicable disease. That impression is correct and lends weight to the opinion of those who believe that communicable disease can be safely cared for quite easily in any well organized surgical ward where a simple, foolproof technic is conscientiously observed by all.

The dressing of wounds can be facilitated by a truck, figure 235, that provides the necessary items as well as a means of disposing of soiled linen, dressings, and instruments. The use of individual dressing kits, figure 233, 2, and a safe sterile transfer forceps, figure 17, insure against cross contamination. A shelf mounted on a crane attached to the right rear corner of the dressing truck is readily adjusted to support a sterile field over the patient. The waste container is also mounted on a crane so that it can be swung near the patient to receive soiled dressings. This container is fabricated of stainless steel and is just large enough to hold a waterproof paper bag with about 4 cm. of the bag protruding. The flaring, funnel like top slips inside the upper edges of the bag to fasten the latter securely in the container. When the bag is two-thirds full, the flaring top is removed, the bag closed and disposed of in the "contaminated waste can" (Chapter XX).

Soiled instruments are accumulated in the instrument pan. They are cleansed and sterilized simultaneously, figure 110, before they are returned to the central supply room. Unused dressings and instruments

are gathered together into the sterilizing envelope and the flap of the latter is tucked over a bar in a recess designed to accumulate used kits. Linen, wrappers, towels, etc., are dropped into a small hamper bag suspended from a ring set in the top of the truck. When full, this bag is closed snugly and a "communicable" tag is attached. It is sent to the laundry for processing as described in Chapter XV.

INCONSISTENCIES IN TECHNIC

Inconsistencies in technic are far too common, and much in this book is frequently violated or even unknown to successful surgeons without deleterious clinical results. Students wonder why some surgeons seem to have little difficulty with wound healing, while others are always embarrassed by infection. The success of the group who have good results despite apparently careless asepsis stimulates contempt for aseptic technic in the student who does not fully understand the complexity of the factors determining whether or not the inevitable contamination which occurs even with the most ideal technic will cause sepsis. The virulence, kind, and number of contaminating bacteria are important factors in determining the incidence of infection. Organisms acquired in environs where there are other wounds or where disease is prevalent are more facultative than are those in isolated regions or clean homes.¹¹ Symbiotic types implanted together cause infection more readily than do other bacteria.

The resistance of many patients to infection is great, either because of their robust health or because they have developed a specific resistance against the implanted organism by previous exposure. Debility, malnutrition, metabolic disease, all undermine the patient's resistance so that the

¹¹ Editorial: Secondary Streptococcal Wound Infection. *N.E.J.M.*, 230: 68., 1944.

PRACTICAL DRESSING CAR

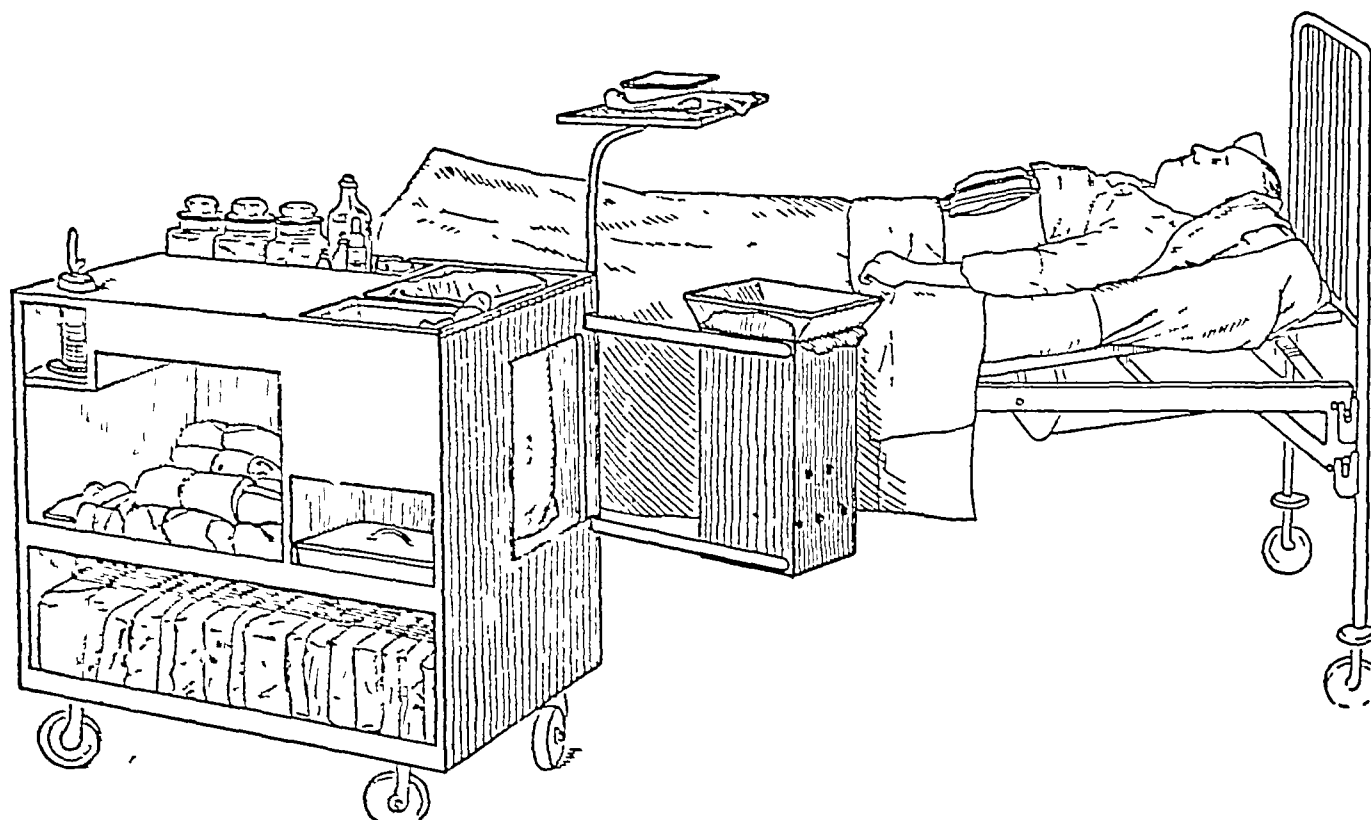


FIGURE 235

true skill of a surgeon is measured by his success with the poor risk or elderly patient.

The individual surgeon's technic is the most important factor in determining the kind of wound healing that will occur. The details of technic which favor kindly healing appear insignificant but are of the utmost importance because their careful application leaves a wound in which there is no culture media for the few organisms which are inevitably implanted. The skillful surgeon avoids excessive tissue injury due to blunt dissection or needless exploration of tissue planes which frequently make a wound ten or twenty times as large as another of equal length. He keeps the wound moistened with isotonic saline so that the surface cells are not desiccated. Ligatures include only the tip of the bleeding vessel so that nubbins of sloughing tissue do not result distal to each tie. Sutures are carefully placed and are pulled only tight

enough to approximate tissue without causing its strangulation by occluding the blood supply. Chemicals, such as germicides which devitalize wound surfaces, are not put into wounds. Finally, closure is carried out carefully so that there is a minimum of space left in which tissue fluids can accumulate to support bacterial growth.

Technical considerations are responsible for the reduction of the inevitable contamination of the wound by organisms from the skin, air, or hollow viscus to a minimum so that the reparative process is not unduly handicapped by the need for eliminating bacteria. Disinfection of the skin is possible but because it is usually a relative matter, the skin should be excluded from the operative field by applying sterile drapes up to the line of incision. Careful walling off of an infected or potentially septic field from the remainder of the wound is the earmark of a skillful surgeon who limits poten-

tial contamination to the field already involved. Properly used ultraviolet radiation decreases the amount of air borne contamination. Proper masking does much to prevent gross spitting into the wound and hence should be enforced. Because masking is only relatively effective, however, those who harbor virulent organisms in their nasopharyngeal passage should be barred from the operating room. No one with a cold can conscientiously rely on a mask to keep his patients safe from infection.

Kindly wound healing is more likely to occur when a minimum of foreign bodies is left in the wound. Only sufficient suture material to gently approximate the tissues should be used. Perfect hemostasis leaves a dry wound without blood clots to nourish bacteria. The choice of suture material itself influences wound healing¹² because nonabsorbable sutures provoke a minimum of tissue reaction, whereas absorbable surgical gut stimulates sufficient reaction to cause its disintegration and removal. Nubbins of tissues distal to ligatures and large avascular pedicles are foreign bodies which serve as culture media for organisms. Drains invite infection which they are intended to avoid.¹³ In compound injuries two factors play a role — the extent and location of the wound and the promptness, type, and thoroughness of treatment. Wounds containing much traumatized muscle, fascia, and bone offer greater opportunity for over-

whelming bacterial growth, where the blood supply is impaired by damage to, or ligation of, large vessels or by extrinsic pressure caused by a hematoma, displaced fracture, or swelling confined within a tight fascial compartment. Tourniquets and tight fitting casts often compromise blood supply sufficiently to accelerate infection. The anatomic site also influences the incidence of infection. Wounds of the head, neck, thorax, and back are prone to heal kindly unless they communicate with the cavities they enclose. The muscular areas of the arms, buttocks, and thighs are susceptible to infection.

Finally, those who have watched the work of skilled plastic surgeons realize that adequate dressing, immobilization in a functional position, and elevation to prevent edema and interference with blood flow are factors which often turn the balance in favor of prompt wound healing. Because the surgeon cannot evaluate the various factors influencing wound healing, except in retrospect, it is his duty to control the tangible factors to the best of his ability. Certainly, the aseptic treatment of his wound is an inherent right of every patient. Because so much of asepsis depends upon institutional effort, it is the responsibility of trustees and administrators to provide the facilities and develop the discipline essential for safe surgery.

¹² STAMBAUGH P. Silk Technique. Experimental Observations, *Surgery* 7:9-23. 1940.

¹³ DUFFY J. L. and BOTTORF T. W. The Use of Silk in Thyroid Surgery. *Surg. Gyn. & Obs.*, 69:441-445. 1939.

CHAPTER XX

CONTROL OF COMMUNICABLE DISEASE

Often we wait for a catastrophe such as a fatality or a series of deaths or an epidemic in our own hospital to call us to account for our methods

—FRANK L. MELENEY, 1935¹

Communicable disease is of interest to operating room personnel for several reasons. In a broad sense, aseptic technic is the control of the communicable diseases, supuration, purulent edema, hospital gangrene, erysipelas, and traumatic tetanus, those scourges which formerly limited surgery to the treatment of desperate conditions. Now aseptic technic is taken for granted and wound infections are often thought of as being quite apart from communicable diseases, but the problem of controlling wound infections is comparable to that of controlling measles. Operating room supervisors are often confronted by bewildered students seeking explanations for inconsistencies in communicable disease technic which violate the principles taught in the operating room. Occasionally, a patient with scarlet fever must have an appendectomy performed and the control of the communicable disease becomes an acute problem for the operating room supervisor. Patients with communicable disease, often unsuspected, are found everywhere in the hospital and are a hazard to the personnel and other patients. They must be properly cared for wherever they are discovered.

¹ MELENEY, F. L. Infection in Clean Operative Wounds, *Surg., Gyn. & Ob.*, 60:264, 1935. By permission of *Surgery, Gynecology & Obstetrics*.

Finally, the gross dislocation of the population during wartime or disaster makes widespread knowledge of methods for the control of communicable disease imperative.

Confusion regarding communicable diseases exists because the terms "contagious" and "infectious" have not been precisely defined. A newer term, "communicable," is better and should be given preference because it clarifies the application of control measures.² The concept of a communicable disease recognizes that the etiologic organism may be transferred in a variety of ways to a well individual. The mode of transmission or the degree of communicability varies greatly. With chronic infections, like actinomycosis and tuberculosis, or in diseases with a long period of incubation, such as typhoid fever, the degree of communicability and the mode of transference are difficult to determine because the relationship between the original sufferer and the new victim is often impossible to establish. Yet statistical studies on student nurses or medical students clearly point to the easy communicability of tuberculosis and link the development of the infection with the beginning of the student's contact with patients. If tuberculosis was an acute infection with a

² ROSENAU, M. J. *Preventive Medicine and Hygiene*. New York: D. Appleton & Co., 1928.

short incubation period, like diphtheria, the proper point of view toward its control would be spontaneous

The majority of the agents responsible for communicable disease enter the body through the mouth. Food, water, fingers, dust, and mouthed objects are the mechanical means of transferring the infecting organism. The observance of ordinary sanitary habits protects against many communicable diseases. Those who wash their hands before eating and following defecation and keep their fingers away from the mouth and nose do much to protect their good health. The remaining channels by which infection enters the body, the respiratory tract and the skin, are also susceptible to control.

Communicable disease can be cared for quite easily in a general hospital where there is no provision for isolation, and no hospital can escape the responsibility for providing adequate protection for patients and personnel. Early diagnosis and definition of channels of infection are imperative. A minimum of equipment and a maximum of intelligent cooperation of all those who contact the patient, plus widespread knowledge of the factors responsible for the spread of communicable disease, are fundamental requisites for success. The chief aim of isolation technic is the concentration of communicable disease by the meticulous avoidance of spread to uncontaminated objects — the reverse of asepsis. Because most of the organisms responsible for communicable disease are moist and nonsporeforming when eliminated from the host, sanitation rather than sterilization can be relied upon to destroy them. This fact expedites the technic of caring for patients with communicable disease without sacrificing the personal safety of the nurses or attendants.

A successful communicable disease technic can be elaborated if the diseases are

grouped according to their most important channels of infection and their degree of communicability.³ The optimum point of control is the channel of infection. The diligence with which that channel of infection must be controlled depends upon the degree of communicability of the disease. A classification of communicable disease which permits the application of a simplified technic is shown in figure 236. The grouping according to mode of transmission is obvious. The designation of degrees of contact with the channel of infection, figure 237, is the key to expediting the technic so that it is practicable. The table correlates the mode of transmission with the degree of contact and outlines the precautions necessary in each case. Figure 238 outlines the sanitation necessary for disposing of equipment, linen, etc., used in caring for patients with communicable disease. Here again, the task is simplified because only the items which serve as a channel of infection need be sanitized.

A technic based upon the tables can be applied in the hospital or home by anyone who understands the principles upon which they are based. Because local conditions vary greatly, only the bare outline of a technic for the control of communicable disease will be presented. When communicable disease has been diagnosed, the doctor immediately defines the channels of infection by ordering observance of communicable disease precautions of the type indicated in figure 236. The degree of contact with that channel of infection determines the elaborateness of the precautions which must be taken. Only three degrees of contact are specified to simplify administration but it must be recognized that a close division is often impossible. The hazard of the contact is governed by the intimacy and

³WEARN, J. T. *Medical Isolation Technique*. University Hospitals of Cleveland, November 1937.

the duration of the exposure to the patient or contaminated equipment

Close contact has been defined as intimate and prolonged association with the patient, such as is inevitable when making a physical examination, giving treatments, carrying on morning and evening care, feeding a very ill patient or taking the temperature of a helpless patient. Because visitors cannot be adequately instructed, they are considered as having close contact with the patient except where the discharge from localized infection is controlled by adequate dressings.

Moderate contact is defined as brief exposure such as occurs during local examinations, adjusting the bedding, taking the temperature, helping with a tray or aiding the patient with the bath. The contact must be limited to the hands and care must be taken to prevent contamination of the uniform. Ward maids and other non-professional workers who perform services which do not require contact with the patient are included in this classification.

Minimal contact is considered to be a brief visit to the patient to remove the tray, check on the condition of the patient or to answer the call bell. At most, there is only hand contact.

It is incumbent upon the hospital to elicit the cooperation of the patient and educate him in simple measures which aid in checking the spread of his disease.

Equipment for communicable disease technic is illustrated in figure 239. The patient's bedside table is burdened with only one piece of equipment for the care of communicable disease. It is the paper bag which is attached to the side of the table to accumulate thermometer wipes, swabs, and tissues used in place of handkerchiefs. An extra bedside table is provided for the supplies essential for actual care. The top of this table provides space for a basin filled

with 1:1000 aqueous Zephiran solution and a stack of paper towels. The top shelf provides space for a clinical thermometer stored in a thermometer glass containing 1:1000 aqueous Zephiran, a supply of gauze or paper wipes in a paper cup, a daub of petroleum jelly in a paper cup if a rectal thermometer is being used, talcum powder and bathing lotion. If rubber gloves are indicated, they are also kept here. On the bottom shelf, equipment, such as icecaps, hot water bottles, and the like, is kept. A large pail is located on the floor beside the table. A chair, a hamper frame, and a white duck bag complete the bedside equipment. If but one nurse is responsible for the patient's care, a hook is provided for her gown.

If the patient is being cared for on the open ward, the curtains are kept drawn on either side of the bed for groups 1 and 2 and a portable ultraviolet radiation barrier can be temporarily installed to prevent cross-contamination. It must be recognized that the factors described in Chapter XIII are of equal importance in communicable disease technic and that ultraviolet radiation supplements control but does not eliminate the need for "reverse asepsis."

The prime essential for success is time in which to perform the various steps of the technic conscientiously. Too heavy a case load invites short cuts and slipshod technic which result in disaster. A second essential is the provision of adequate supplies so that caps, masks, and gowns are available at all times. Hand-washing facilities must be ubiquitous. This does not mean that lavatories and running water must be provided everywhere but rather that basins with a germicidal detergent are placed at each isolation unit so that hands can be disinfected quickly and comfortably as a routine measure. The hands are then dried on paper towels which are discarded into the waste pail. If rubber gloves are worn, they are

CLASSIFICATION OF COMMUNICABLE DISEASE BY CHANNEL OF INFECTION

Group I Discharge from mouth and nose, therefore, chiefly air borne — respiratory diseases

A. Highly communicable

Chicken pox	Influenza	Poliomyelitis
Diphtheria	Measles	Prittacosis
Encephalitis lethargica	Mumps	Smallpox
Menngococcus meningitis	Pertussis	Virus pneumonia
German measles		

B. Less communicable

Pneumococcus pneumonia	Vincent's stomatitis
Pulmonary tuberculosis	Scarlet fever
Streptococcus sore throat	

Group II Excreta, therefore food or fomites borne. Flies must be controlled — "enteric diseases"

Amebic dysentery	Poliomyelitis
Bacillary dysentery	Tuberculosis of the gastro-intestinal and genito-urinary tracts
Typhoid fever	

Group III Discharge from local infection

A. Wounds

Actinomycosis	Surgical tuberculous lesions
Anthrax	Tetanus
Gas gangrene	Tularemia
Suppurating wounds	

B. Discharges from orifices

Gonorrhea — eyes and genito-urinary tract
Tuberculous mastitis
Trachoma
Puerperal sepsis

C. Local or skin infections

Erysipelas	Impetigo
Fungus infections	Leprosy
Glanders	Primary and secondary syphilis

Group IV Parasitic infestation

Scabies
Pediculosis
Ticks

Group V Diseases communicated by vector other than man

Malaria	Typhus
Rocky Mountain spotted fever	Undulant fever

FIGURE 236

TECHNIC FOR DISPOSAL OF CONTAMINATED EQUIPMENT AND SUPPLIES

Classification	I	II	III
Gown and mask	launder after each use	launder after each use	
Gloves		disinfect after each use 1 wash with limepaste 2. rinse 3 boil 15 minutes 4 steam sterilizer 30 min — 121 C	same as instruments
Instruments	wash or wipe with 1:1000 NaOCl	wash or wipe with NaOCl	sterilize in 2% NaCO ₃ or 10% soap 100°C — 30 min
Dressings			burn
Dishes	boil 15 minutes	boil 15 minutes	usual care
Food Excreta		protect from flies wrap dry food in paper and burn boil liquid 15 min steam excreta or bedpan mix equal quantity of 5% chlorinated lime with excreta and let stand for one hour boil bedpan 15 min. boil bath water 15 min.	
Dry linen	gather into clean, heavy duck bag marked communicable empty into breaker with aseptic technic throw bag in break 20 min. with cold water add at least 3% soap heat to boiling rinse treat as ordinary laundry		
Wet linen		wrap in linen sufficiently dry to prevent soaking through, then treat as for Group I	
Woolens	steps 1-5 as above heat to 71 C — 30 min rinse finish as other woolens		
Terminal	launder linen, blankets, curtains and screens disinfect furniture, bed, and equipment by washing with germicide wash floor and dust catching nls, shelves with germicide dry pillows and mattresses thoroughly before using again disperse aerosol to disinfect cubicle steam sterilization essential for pillows and mattresses in Group IV		

FIGURE 238

washed in the Zephiran before removal. They are turned inside out as they are removed and carried in a clean paper towel to the utility room for sanitization. A third essential is cooperation on the part of those who collect the contaminated articles, launder them, and return them to circulation. A huge inventory of supplies is a liability when it is piled in the laundry instead of on the linen supply shelves. A fourth essential consists of appropriate facilities for the collection and disposition of discarded articles. Too often, such items are permitted to accumulate in the utility room or clutter up the floor in the corridor because facilities for their prompt disposal are not considered essential. Dry waste is wrapped in clean newspaper and deposited in a "communicable" waste can. This can is emptied directly into the incinerator by a properly instructed member of the housekeeping staff. It is most convenient to collect such cans at a set hour of the day, incinerate their contents and clean and sanitize the cans by exposing them to live steam before they are returned to the individual wards. Lastly, the technics for the control of air-borne bacteria discussed in Chapter XIII must be understood and diligently applied.

Insoluble food is collected in a waterproof paper bag. The bag is reinforced by wrapping it in several layers of newspaper and discarded in the communicable waste can.

Dishes are most readily disposed of by loading them into a dish sterilizer to which sufficient detergent is added so that the dishes are cleansed while they are boiled for fifteen minutes. Because most hospitals do not have adequate dishwashing or sterilizing equipment, the general problem of providing sanitary dishes for patients and personnel is acute.

The sanitization of dishes can only be proved by bacteriologic examination but bacteriologic tests are ineffectual in that

they can only be done periodically and have no significance in the routine handling of tableware since it is impossible to wait for culture reports. A practical routine is frequent inspection of the dishwashing process with occasional bacteriologic examinations to serve as a check on the inspector. When efficient detergents are used⁴ almost all bacteria are removed by the dish water and the dishes are left clean, whereas disinfection of incompletely washed dishes, either by a rinse in germicide or exposure to ultraviolet radiation is ineffective. The ultimate test, therefore, for sanitization of dishes is perfect visual cleanliness. The grossly unclean dish or piece of silverware is not dangerous because it is not likely to be used. In inspecting tableware for cleanliness, it is imperative to pay attention to thin, almost invisible films of food residue which shelter underlying bacteria. Special equipment is available for detecting greasy films on glassware. The water break test described in Chapter XVI is a useful procedure.

A more reliable method is the routine supervision of the dishwashing process. The maintenance of a good detergent solution at a minimum pH of 10.5 is essential. The solution must be clean and should have a temperature above 50°C. Rinsing in clean water at 80°C is sufficient to turn out sanitized tableware. The pH value can easily be determined periodically by dipping a small fragment of phenolphthalein test paper into the dish water. Sufficient detergent should be added to maintain a deep pink color. If the test paper remains light pink, the water is too weak; if it turns deep red, the strength is unnecessarily high.

Many sanitized dishes are contaminated by drying with dirty towels. The safest

⁴HALL, G. O. and SCHWARTZ, C. Sanitary Value of Sodium Metaphosphate in Dish washing, *Ind. & Eng. Chem.*, 29:421, 1937.

technic is to rinse chinaware with water sufficiently hot so that drying occurs, due to evaporation. Silverware usually cools too rapidly, however, and must be dried by toweling. Wherever towels are used, an adequate supply must be available and each one used should be discarded before it becomes badly soiled. Tableware should be handled as little as possible after it is sanitized. Dish handlers with respiratory infections must be masked. Dishes must be picked up by their edges, cups and silverware by their handles, and glassware by the base if the chain of sanitization instituted by proper washing is to remain unbroken. In relatively closed communities, such as hospitals, much can be done to control epidemics of respiratory and enteric diseases by conscientious observance of these rules.

All excreta, bath water, and mouth wash are carefully discarded into the lowest part of the utility room hopper and flushed away with cold water followed by thorough rinsing with hot water. Splashing and spattering must be avoided. A tiny pinch of methylene blue added to the bedpan just before it is emptied is a ready check on technic. The bedpans, urinals and basins should be sanitized by boiling for fifteen minutes. In communities where sewage disposal practice does not provide adequate control for enteric disease, these fluids must be disinfected by the addition of chlorinated lime. A volume of 5% solution equivalent to that to be disinfected suffices. The period of exposure is one hour.

The following description of the morning care of a patient suffering from communicable disease is indicative of the type of procedure which must be elaborated to care for all of the patient's needs, suitable modifications being made to cover each subdivision of the classification in figure 236.

All the supplies are carried to the isolation unit as the initial step in beginning a procedure.

They can be placed in their respective positions without protection, other than masking, if care is used to prevent self contamination. Clean towels and bedding are piled on the chair, figure 239, 2. A paper bag, clean hamper bag, and folded newspaper are placed on the lower shelf of the extra bedside table, figure 239, 3. A basin of warm water is placed on the bedside table, figure 239, 4. The wrist watch is removed and placed on a paper towel on the rear corner of the extra table, figure 239, 5. A precaution gown is next put on.

In a ward where many individuals contribute to the care of the patient, it is best to provide fresh gowns for each person who enters the isolation unit. Otherwise, carelessness on the part of one individual subjects subsequent persons to contamination over which they have no control. Where one individual is charged with the care of the patient, a single gown can be used throughout the day. A technic for handling the gown is shown in figure 242.

The routine care of the patient is performed. Soiled linen is rolled and dropped into the hamper bag as soon as it is removed from the bed, figure 240, 6. A gauze pad dampened with 1:1000 aqueous Zephiran is used to dust bed, tables, and chair and is then discarded into the waste pail. Three sheets of newspaper are opened out and placed on the floor near the extra table, figure 240, 7. The paper bag attached to the bedside table is discarded on the newspaper and a clean one put in its place, figure 240, 8. The contents of the waste pail are dumped onto the newspaper, figure 240, 9, and the papers are rolled into a tight bundle, figure 240, 10. Two layers of newspaper are spread on the floor at the entrance to the isolation unit by another nurse and the bundle of contaminated waste is deposited in the center, figure 241, 11. The second nurse wraps it snugly for disposition in a

waste can provided especially for discard from patients with communicable disease. The hamper bag is removed from the frame, figure 241, 12, the drawstring is pulled tight and knotted. The second nurse brings another hamper bag to the door of the unit and helps spread the top of the second bag so that the one containing the contaminated linen can be inserted into it, figure 241, 13. The second bag is taken out of the isolation unit, closed tightly, and labeled with a red tag marked "communicable," figure 241, 14. A clean hamper bag is suspended on the frame.

The nurse then removes her gown and discards it into the fresh hamper bag. She empties the bath basin in the utility room, using care not to contaminate push plates, faucet handles, and the like en route, and puts the basin in the utensil sterilizer. The hands and lower arms are then rubbed vigorously with 1:1000 aqueous Zephiran for two minutes; the hands are dried on paper towels and the watch is put on, figure 241, 15. The paper towel protecting the watch from contact with the table top is discarded, figure 241, 16.

The basin of Zephiran should be replenished daily. The clean hands are protected with paper towels while the basin of Zephiran is carried to the utility room and emptied. The basin is sanitized by boiling. The paper towels which protected the hands are crushed with the contaminated surfaces inside, wrapped in a fresh towel or piece of newspaper and discarded into the communicable waste can.

When the isolation unit needs cleaning, it must be done under the supervision of a nurse who is willing to watch the procedure carefully enough to guarantee its safety. Cleaning is done with a 1:1000 solution of chlorinated lime or 1:2500 solution of Zephiran. A damp mop must be used rather than a broom or dry mop, both of which

stir up dust which is a dangerous source of organisms.⁵ The usual care of the mop and pail suffices when sodium hypochlorite solution is used.

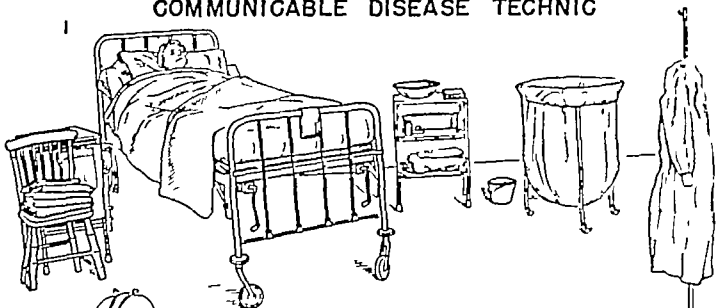
Sufficient equipment must be provided so that contaminated basins and the like can be accumulated in the utensil sterilizer until it is loaded instead of sterilizing those from each patient separately. The equipment is sanitized in boiling water for fifteen minutes and then carefully washed to make it appear clean.

When a gown is used repeatedly by the same individual throughout a day's work, the following technic is justifiable. A well-fitting gown is essential to avoid contamination. To remove a gown from the hook, the hands are slipped in the back opening, avoiding contact with the contaminated side of the gown. The shoulder seams are grasped and the gown is lifted from the hook, figure 242, 1. The hands and arms are slipped into the sleeves just as described in figures 160 and 161. At the stage where the circulating nurse would help to complete donning the gown, the nurse helps herself by grasping the top edge of the collar and snugging it around her neck, figure 242, 3, so that the top tie can be fastened, figure 242, 4. The back edges of the gown are grasped in the fingers so that the left side can be tucked beneath the right, figure 242, 5, 6, to completely cover the uniform. The belt is crossed in the back, figure 242, 7, and tied in the front with a bow knot, figure 242, 8. The sleeves of the gown are slipped upward to expose the lower half of the forearms when indicated. The sleeves must not be rolled. If the cuffs are too loose to hold the sleeves up, rubber bands should be applied to prevent the cuffs from slipping down over contaminated arms.

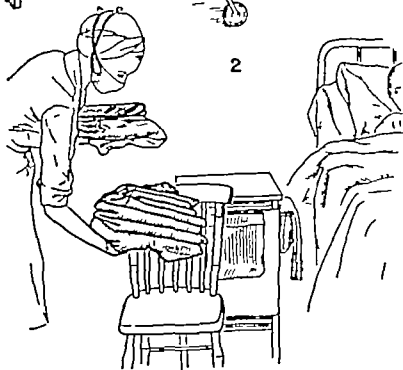
⁵ WALTER, W. G. and HUCKER, G. J. Beta Hemolytic Streptococci Isolated from Public Room Floors, *J. Infect. Dis.*, 71: 237-240, 1942.

COMMUNICABLE DISEASE TECHNIC

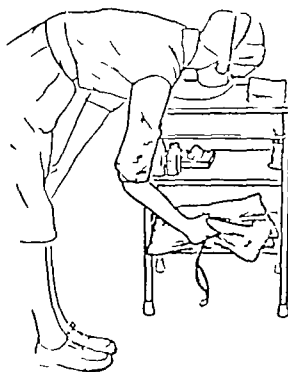
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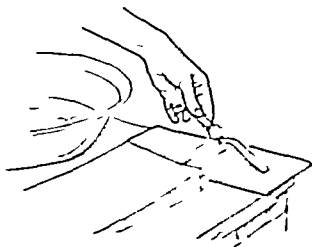
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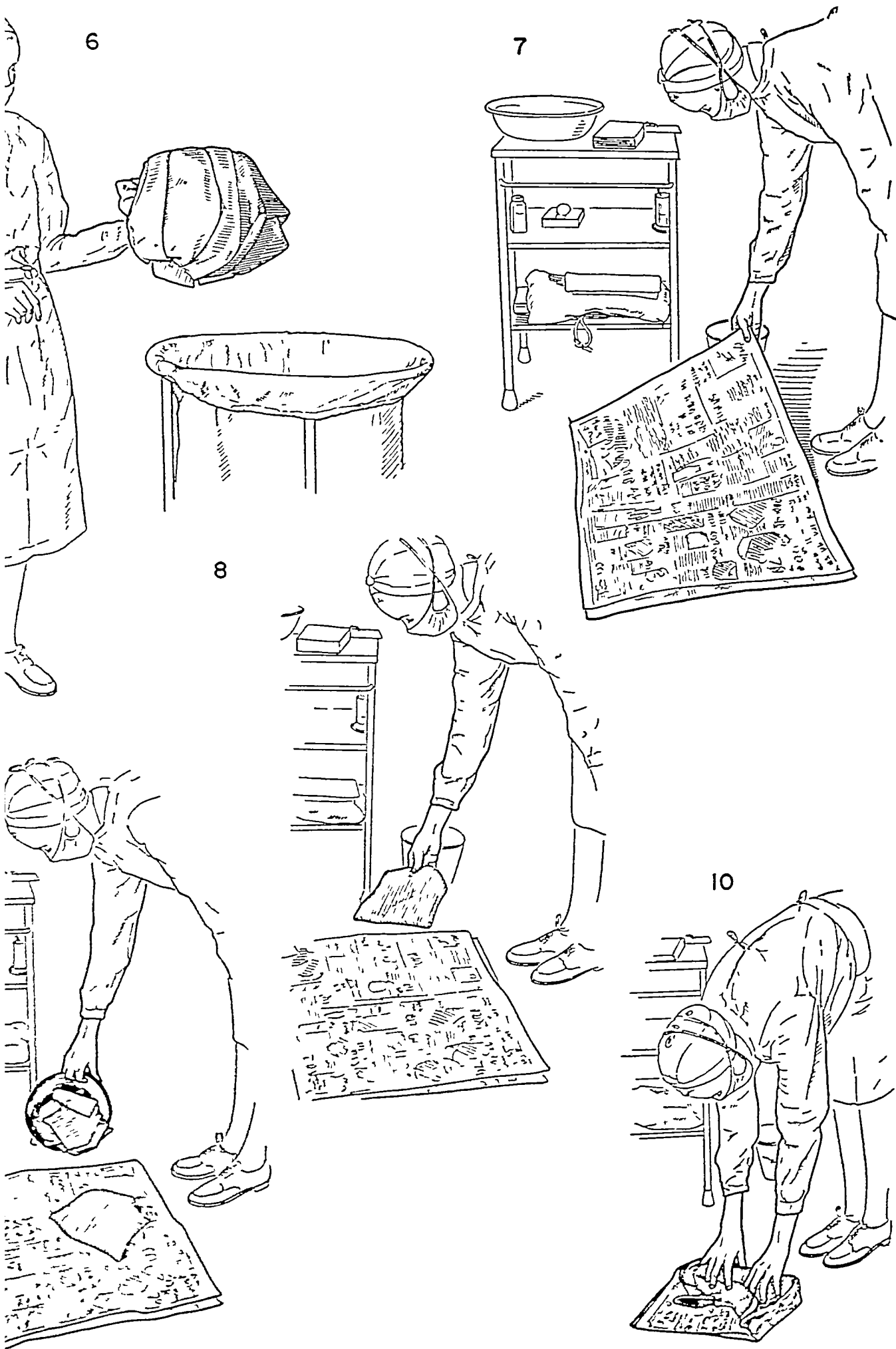
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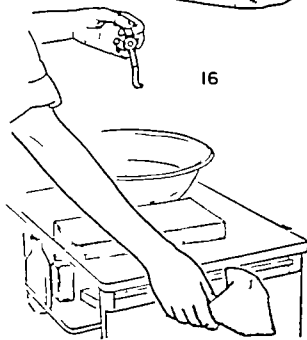
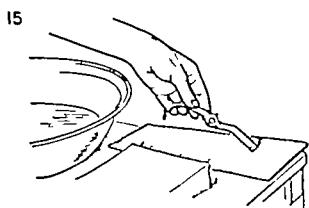
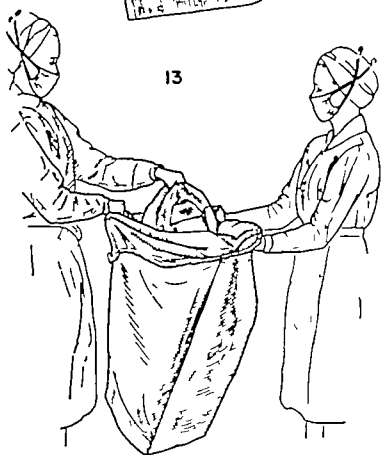
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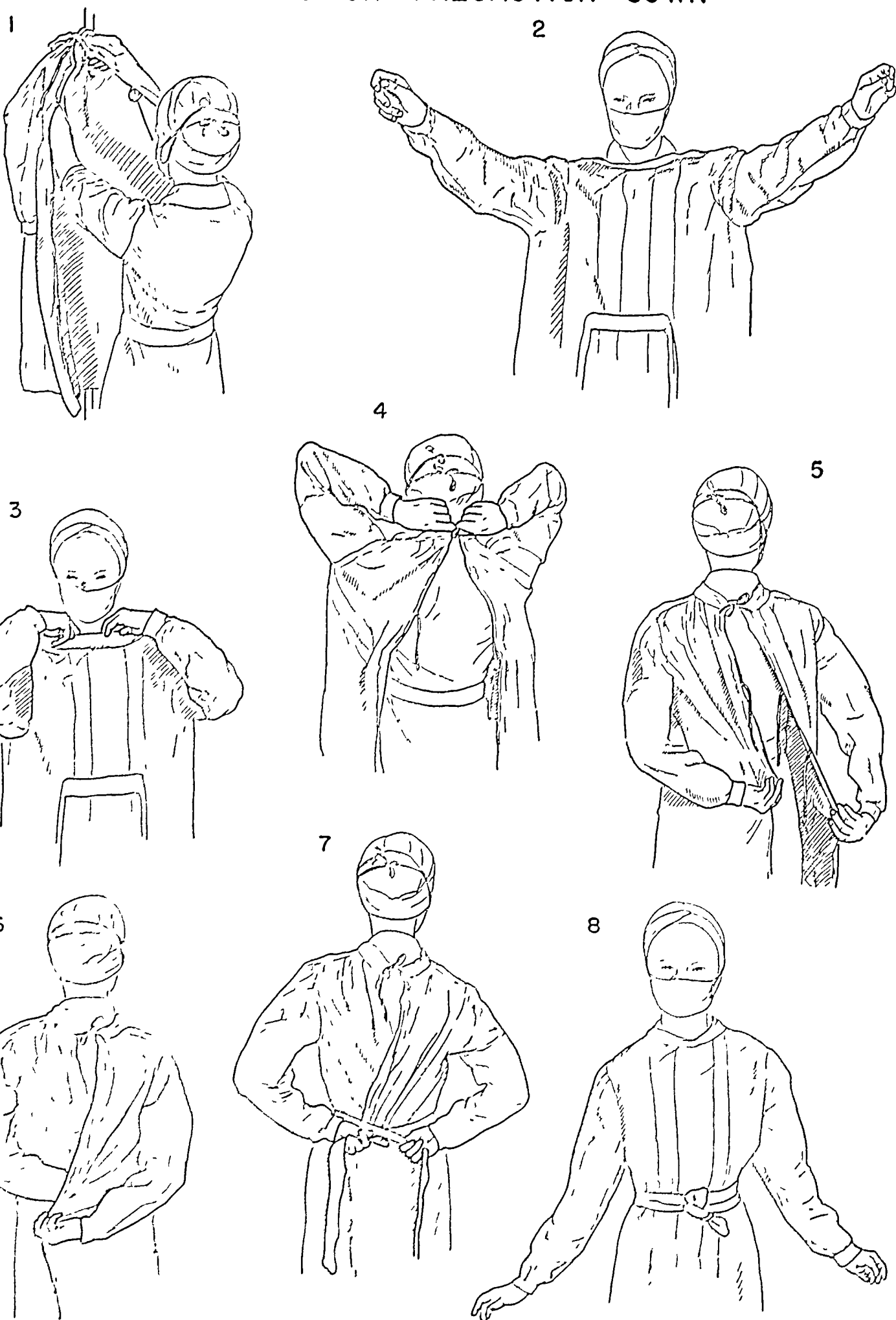
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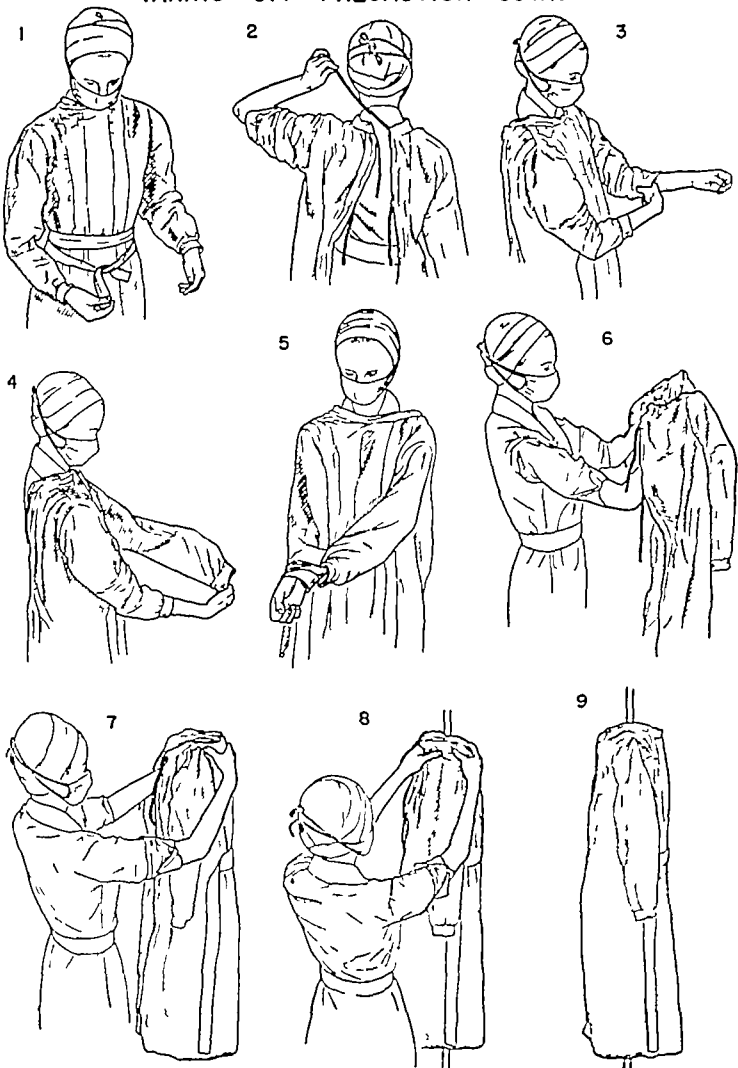
COMMUNICABLE DISEASE TECHNIC



PUTTING ON PRECAUTION GOWN



TAKING OFF PRECAUTION GOWN



Gowns are removed by untying the belt and dropping it to the sides, figure 243, 1 The sleeves are pushed up to the elbows and the hands and arms are washed The tie at the neck band is next loosened, figure 243, 2 Two fingers of the right hand are slipped beneath the left cuff and the cuff is pulled down over the hand, figure 243, 3, 4 The right cuff is grasped in the left hand and stretched sufficiently so that the cuff works off the right hand without causing inversion Care must be taken not to contaminate the hand with the left sleeve, figure 243, 5 The gown is slipped off by working the hands up the inside of the sleeves until the shoulder seams have been reached The shoulder seams are grasped and the gown is folded longitudinally so that the uncontaminated surfaces are in apposition, figure 243, 6 The collar is then propped upward with the thumbs and grasped at the center front with the right hand as it is slipped from the inside, figure 243, 7 The left hand grasps the approximated edges of the back of the collar and the whole is gathered together toward the center, figure 243, 8 The gown is then hung on the hook at the level of the shoulder seams, figure 243, 9 If the gown has been wet, it is discarded in the hamper

TERMINAL CARE OF A UNIT (ROOM)

The purpose of terminal care is to disinfect the room and its contents and prepare it for occupancy The equipment which must be provided includes three sections of newspaper, two bath basins, a pail containing a solution of 1 1000 sodium hypochlorite, several pads of washed gauze, and a pressure atomizer containing a pint of 0.5% sodium hypochlorite solution Two sections of newspaper are spread on the floor near the door of the unit The cleaning equipment is put on one section The third section is folded into quarters and placed

on top of the extra table The wrist watch is removed and a precaution gown put on with usual technic All the equipment suitable for sanitization by boiling is collected in one bath basin That which must be taken care of by chemical disinfection is collected into the second basin All dried waste is accumulated on the second section of newspaper The linen and blankets are stripped from the bed and put into the hamper The bed is washed thoroughly, particular care being taken to clean the rails The springs need not be cleaned mechanically The bedside table is washed thoroughly The remaining furniture and the window ledges are dusted with a pad of gauze dampened in germicide The newspaper which was folded in quarters is opened and placed, clean surface down, on top of the bedside table The basin of Zephiran and the towel upon which the watch was placed are moved to the clean newspaper and the second table top is washed If the walls have been grossly soiled, they should be washed, otherwise, they can be disregarded The hamper bag is next removed from the frame, closed tightly, and placed on the floor The hamper frame is cleaned The sponge used for washing and dusting is discarded on the newspaper on which dry waste is piled A second nurse spreads several sheets of newspaper on the floor outside the unit to receive the bundle of dry waste This nurse also holds open the clean hamper bag while the bag containing discarded linen is inserted This second bag is propped on the floor leaving the top open The gown is then removed, rolled up with the contaminated side innermost, and discarded into the open bag The hands are then disinfected The basin containing the utensils, etc., is carried to the utensil sterilizer for sanitization Both the waste pail and the scrub pail are placed in the sterilizer A clean paper towel is spread on

the second table and the basin of Zephuran and several additional towels are moved to that table. The newspaper on the floor is rolled up and placed on the newspaper which covers the bedside table. The hands are disinfected. The basin of Zephuran is carried to the utility room, using paper towels to protect the hands. The Zephuran is spilled into the hopper and the basin is added to the accumulation in the utensil sterilizer. The newspaper on the bedside table is wrapped into a snug bundle, care being taken to touch only the clean under-surface. This package is then discarded into the communicable waste can.

With the mattress doubled over at the head of the bed, the exposed spring is sprayed with the power atomizer to dislodge the dust. The mattress is pulled to the foot of the bed and the upper portion

of the spring is similarly treated. Only sufficient aerosol to dislodge the dust and not enough to moisten the spring and cause its corrosion is used. The nurse then stands in the doorway and atomizes sufficient hypochlorite solution into the room so that there is a distinct fog. The door is then closed for thirty minutes. At the end of this period, the atomizer is again used to develop a fog and the door is closed a second time. At the end of the hour, the floor is dusted with a mop dampened with 1:1000 hypochlorite solution and the room is ready for use.

If the isolation unit cannot be closed, aerosol cannot be employed successfully and washing with germicide must be substituted. If curtains are used to screen the cubicle, they must be removed and placed in the hamper before it is removed from the frame.

CHAPTER XXI

MAINTENANCE OF STERILIZING EQUIPMENT

. . . of all the equipment in the hospital, possibly without exception, the sterilizers are subject to greater neglect or abuse than any other fixtures.

— HENRY HEDDEN, 1925¹

Anyone experienced in sterilizing room activities realizes that the maintenance of equipment is an essential part of the aseptic treatment of wounds. Sterilizers that are out of order are a frequent cause for unsterile goods reaching the operative field. Often those who operate the sterilizers know that they are faulty but find it impossible to elicit the interest and cooperation of mechanics to repair them. The maintenance of sterilizing equipment has two aspects — that of maintaining the proper degree of heat and that of keeping the mechanical parts such as doors, lids, tray lifts, checks, etc., in good working order. Sterilizing equipment is mechanically simple and there is little excuse for the dilapidated condition of sterilizers in most hospitals because a minimum of effort expended in adjusting and cleaning the apparatus and lubricating moving parts keeps the equipment in good order. The prevailing attitude among hospital mechanics that sterilizing equipment is complicated and hence requires the attention of factory servicemen is an excuse for gross ignorance or a desire to avoid responsibility. In fact, sterilizing equipment is so simple that it is not too much to expect those who are sufficiently intelligent to be

entrusted with its operation also to assume some responsibility for maintenance. Indeed, abuse of sterilizing equipment leads to many unnecessary repairs. This chapter deals with the maintenance of the proper heat and stresses the operator's responsibility for protecting the equipment he uses.

All types of sterilizers have much equipment in common and knowledge of function of the various parts of a sterilizer permits intelligent maintenance. All sterilizers have a source of heat. The chief problem encountered here is the deposition of lime salts on the heat exchange surfaces in hard water regions. There are several practicable methods of control. The best is the installation of water softening equipment so that the water supply to sterilizers is rid of the soluble calcium and magnesium compounds which are the source of the scale. If central water softening is not feasible, a softener such as Calgon can be metered into the water supply to individual sterilizers so that peak efficiency is maintained. Lacking water softening equipment, the heating surfaces must be cleansed periodically. The technic for cleansing varies with the kind of scale deposited. In some areas, it is soft and can be scraped or chipped off easily. In others, it is hard and must be dissolved with dilute hydrochloric acid. Electrically

¹ HEDDEN, HENRY. The Sterilizing Equipment of the Hospital, *Mod Hosp*, 24: 298, March, 1925

heated or gas fired sterilizers require particular attention to this detail of maintenance because excessive scale formation may cause overheating with consequent damage to the heating elements

Another solution of the hard water problem is to install central steam generating equipment where the deposition of lime salts is centralized and cared for with routine operation of the boiler. There is no real need for any equipment other than direct steam heated dressing sterilizers and stills so that the avoidance of scale formation can be limited to the care of the central boiler. The objections to this solution are its initial cost and the careful planning required. Automatic oil burning steam generators are available that can be installed and operated economically without the services of a licensed engineer *

STEAM HEATED EQUIPMENT

The essential elements of the conventional central steam plant are diagrammed in figure 32. The source of steam is the boiler which may be fired by coal, oil, or gas. An electrically heated boiler is also available. To insure smooth performance, a higher pressure of steam is maintained in the boiler than in the steam mains throughout the building. A pressure reducing valve located over the boiler maintains a steady pressure in the steam mains. Because the steam in the pipes condenses, provision must be made to remove the condensate from them at various points where experience has shown it to accumulate. Typical points are at the foot of risers or at the end of long horizontal runs, figure 32. Condensate is removed by the simple expedient of inserting a drip pocket to catch the condensate and a return trap to shunt it into the return pipes to the boiler. Installation of such traps rid the steam of excess

Typified by Cleaver Brooks Steam Generators.

STEAM HEATED NONPRESSURE STERILIZER

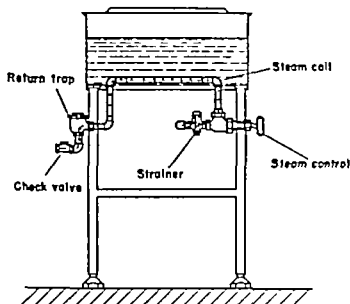


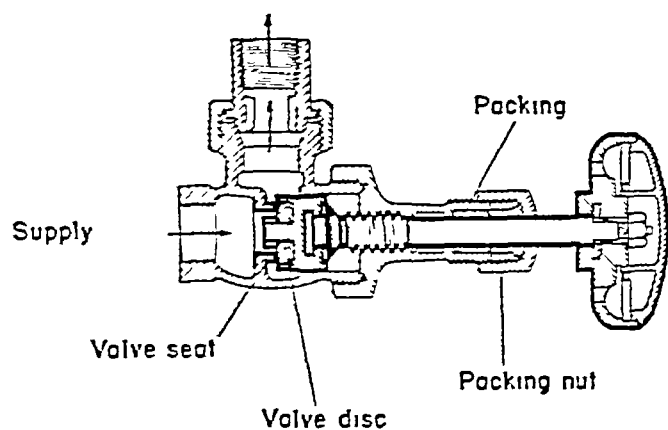
FIGURE 244

moisture and prevents the water hammer which otherwise occurs when steam is first turned into equipment which has been idle for a time. The water hammer results from the collapse of the steam when it strikes condensate that has pooled in low pockets or dead end pipes.

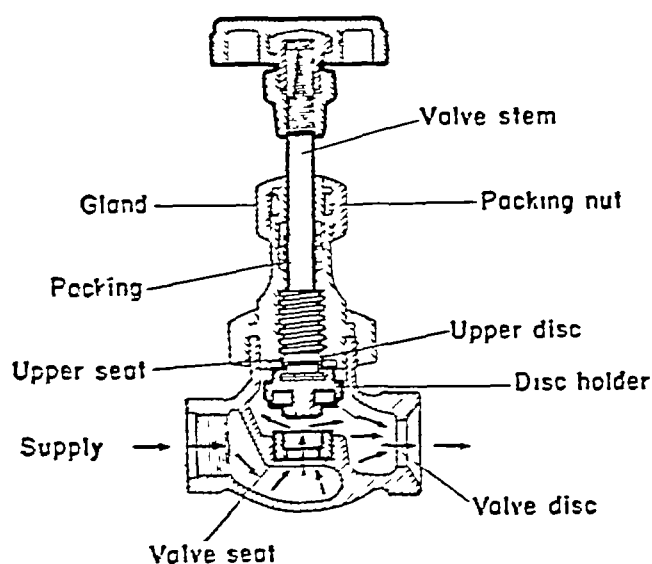
NONPRESSURE STERILIZERS

The simplest circuit for direct steam heat is illustrated by the nonpressure sterilizer, figure 244. The steam supply is controlled by a valve, figure 245. There are two parts of this valve which need maintenance: (1) The packing about the valve stem wears and steam or condensate leaks by. This results in an annoying drip and frequently burns the fingers of those who curl them about the handle of the valve when opening or closing it. The valve stem packing nut can easily be tightened just enough to stop such leakage. In a busy sterilizing room, the stem glands should be checked at weekly intervals. Those who use the valve can prolong the life of the stem packing by opening the valve full every time so that the upper part of the valve stem closes and relieves the steam pressure.

CONVENTIONAL VALVES



ANGLE VALVE (closed)



STRAIGHT VALVE (open)

FIGURE 245

which otherwise is exerted on the stem packing. (2) The valve disc wears just as the washer in a lavatory faucet wears and permits leakage. Continued leakage may result in wire cutting of the valve seat. The valve disc is easily replaced by unscrewing the bonnet nut and substituting a new one. Should the disc holder become worn, it too can be replaced. Excess wear on the valve disc and seat can be avoided by closing the valve just tight enough to shut off the steam. Excessive force jams the disc against

the seat and causes early wear. Such valves are not intended for use as throttles and must be left in either the closed or open position. Use as a throttling valve causes the disc or the seat to become wire cut.

The heating coil is usually made of copper tubing and is proportioned to the capacity of the sterilizer so that rapid heating is possible. It must be kept clean to permit maximum heat transfer from the steam inside the coil to the water in the sterilizer. To effect this heat transfer, steam under maximum pressure must fill the heating coil at all times, and the condensate, which forms as the heat is extracted from the steam, must be removed from the coil continuously. An automatic valve performs this function, figure 246. In sterilizer practice, this valve is operated by a bellows which lifts the poppet from the seat each time cold condensate contacts it.² The condensate is then forced through the orifice in the seat and steam takes its place. The steam heats the bellows, causing it to expand and force the poppet against the seat, closing the valve. The condensate from the trap is returned to the boiler through the return lines which empty into a tank near the boiler. The condensate from this tank is pumped back into the boiler, usually by an electric pump, figure 32. The chief cause of failure of this simple heating system is faulty clearance of condensate which is usually due to faults in the return line or in the boiler room. Occasionally, it is due to failure of a bellows in the return trap so that it does not operate the poppet properly. If the poppet fails to close, back pressure develops in the return line so that the traps connected to that return do not open properly and the heating coils are choked

² NAPIER-ADLAM, T. Steam Traps and Their Characteristics, *Heating & Ventilating*, 34-44-47, July, 1937, 51-54, August, 1937, 62-71, September, 1937, 51-53, October, 1937

STEAM RETURN TRAP

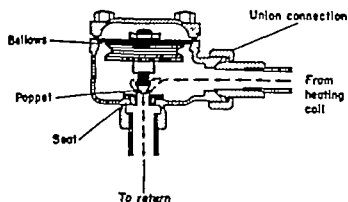


FIGURE 246

with condensate. If the trap fails to open, the individual sterilizer does not heat. To correct the situation, the thermostatic trap is opened and inspected. All dirt is removed. The trap cover is then replaced and steam is blown through the trap for a few seconds to clear all dirt from the steam coil and pipe leading to the trap. The bellows is then replaced and the cover secured. To check the action of the trap, the return line from the trap is opened and the discharge collected into a pail. Normal thermostatic trap action results in an intermittent discharge of condensate with but little steam. A trap that closes tightly for more than fifteen seconds holds excess condensate in the heating coil and hence decreases heat transfer. Continuous discharge of steam through the trap indicates faulty closure.

A check valve is usually installed following the trap to prevent condensate from being aspirated into the heating coil to relieve the vacuum that forms as it cools. Failure of this check valve is indicated by a water hammer which occurs when steam is readmitted to the coil and condenses in contact with the cold water (figure 36).

Some steam heated nonpressure sterilizers are equipped with excess vapor regulators which throttle the steam supply, (figure 27). These devices must be repaired at the factory and should not be tampered

WATER SUPPLY VALVE—BLEEDER TYPE

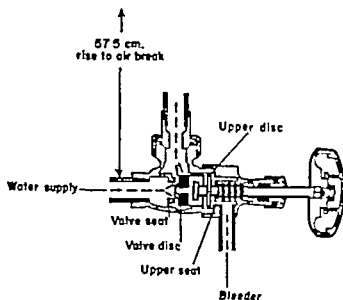


FIGURE 247

with. Where a by pass is depended upon to supply sufficient steam to maintain boiling the sterilizer must be checked periodically to be sure that the water is maintained at its boiling point. This can only be done by a thermometer because convection currents are sufficiently strong at 5° below the boiling point to cause the unwary to mistake them for boiling.

A special water supply valve is used to protect some sterilizers against contamination, (figure 23, 2). This valve differs from conventional valves in that the bonnet is tapped, (figure 247), to provide for a bleeder which carries away any water that accumulates. Leakage past the closed valve up to five liters per minute can escape to the drain through the bleeder. When the valve is opened wide, the upper or back seat is closed to prevent waste of water. To be effective, this valve must be located at least 58 cm below the air break to insure sufficient gravity head to discharge through the bleeder. Leakage at the stem gland is checked by tightening the packing nut. The valve disc or its holder can easily be replaced to correct leakage.

LONGITUDINAL SECTION - DRESSING STERILIZER

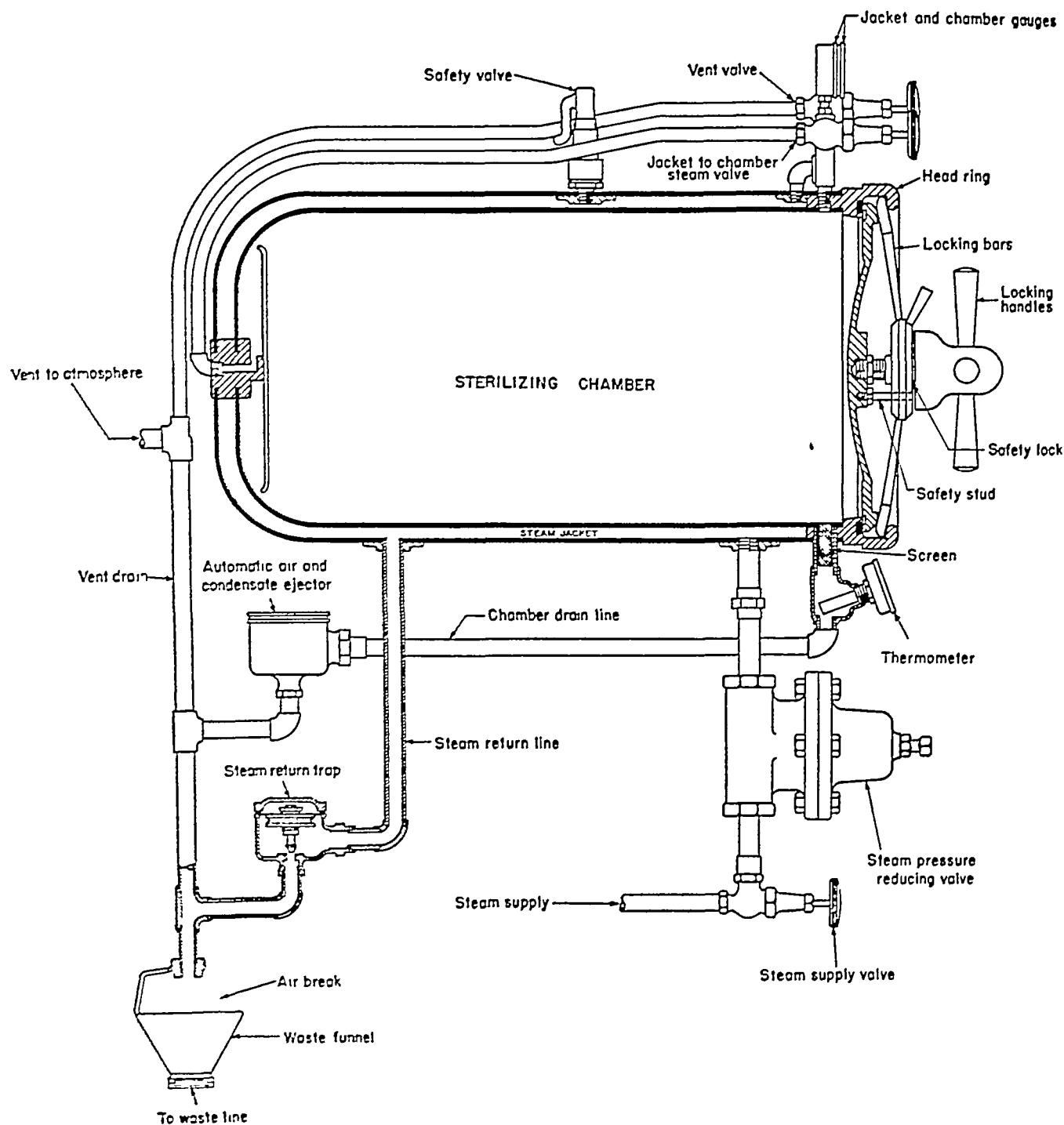


FIGURE 248

PRESSURE REGULATING VALVE

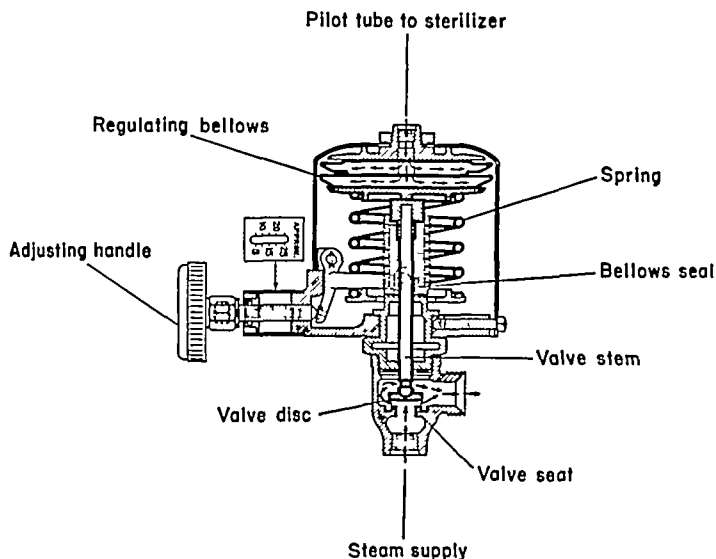


FIGURE 249

Sealed Units Co.-Jen

DRESSING STERILIZERS

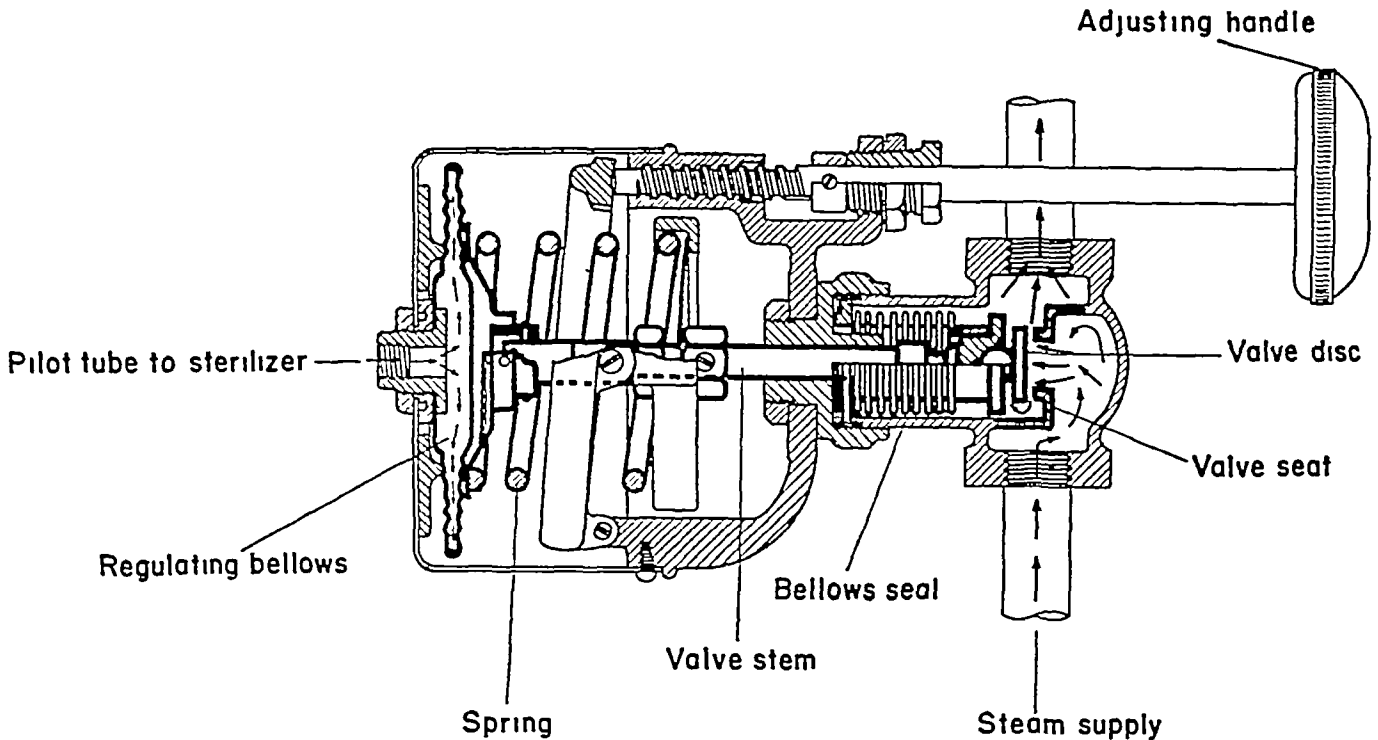
The conventional steam jacketed dressing sterilizer, arranged for direct steam heat, is illustrated in figure 248. The supply of steam is controlled by a valve similar to those shown in figure 245. A leaking steam supply valve floods the pressure-reducing valve and often the jacket of the sterilizer with condensate. When the steam is turned on, it contacts the cold condensate and collapses, causing a water hammer. Enormous strains which upset the adjustment or cause premature failure are exerted on the

delicate parts of the steam pressure reducing valve.

Usually steam equipment is protected against dirt in the steam by a strainer which is installed in the steam line just ahead of the sterilizer. Such strainers should be cleansed just after a new installation has been put into service and at yearly intervals thereafter.

Figures 249-251 illustrate common devices for reducing the pressure of steam as it is supplied from the boilers (usually 3000 to 3800 mm Hg) to the 1536 mm of pressure

PRESSURE REGULATING VALVE



American Sterilizer Company

FIGURE 250

essential for the development of a temperature of 121°C . There are two types of pressure-reducing valves in common use. Figures 249 and 250 illustrate one type which is frequently found on sterilizers in hospitals that have insisted on being able to change the pressure quickly and easily so that varying degrees of heat can be used for sterilization. This shift in temperature is entirely unnecessary and adds needlessly to the cost of a sterilizer and complicates the pressure-reducing valve. Fundamentally this type is a valve, such as that shown in figure 245, that is controlled by the pressure developed in the sterilizer instead of being operated manually. In common with the hand operated valve, there is a valve seat, valve disc, and a valve stem. A bellows seal replaces the packing gland. Instead of the stem being threaded, it is attached to bellows which are expanded or contracted by the

pressure developed in the sterilizer, thus the bellows opens and closes the valve. An adjustable spring holds the valve open until sufficient pressure has built up in the bellows to overcome the spring pressure and permit the bellows to close the valve. The adjustment handle acts by increasing or decreasing the pressure exerted by the spring. Faulty operation of this valve is evidenced by the steam pressure creeping up in the sterilizer until the safety pop valve blows. This condition can be due to two factors: either the bellows leak so that sufficient pressure cannot be developed against the spring to cause the valve to close, or the valve seat and disc do not close tightly. The former condition is accompanied by the leakage of steam from the valve. The latter is usually due to an accumulation of dirt on the seat, preventing tight closure. Oddly enough, this often occurs in new sterilizers.

PRESSURE REGULATING VALVE

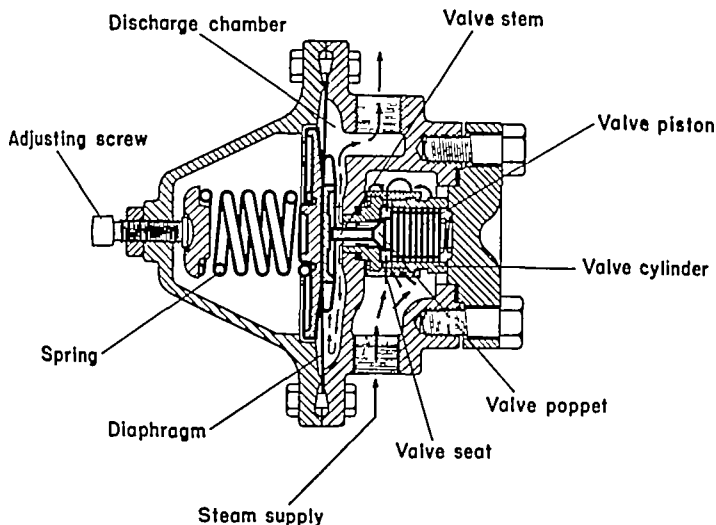


FIGURE 251

A. H. Clark Company

or ones on which steam fitters have recently been at work and is due to dirt which was carelessly left in the pipes being carried into the valves and deposited on the seat. The remedy for leaky bellows is replacement, that for faulty valve action, either simple cleansing of the valve or replacement of the disc so that tight closure is possible. Steam leaking from a valve that otherwise functions properly indicates failure of the bellows seal.

The other type of pressure reducing valve in common use is shown in figure 251. The valve seat is located in the end of a cylinder which carries a piston bearing the poppet

and the valve stem. The stem protrudes through the orifice of the valve to contact a spring loaded diaphragm. A lighter spring beneath the piston presses the stem against the diaphragm. In operation, steam enters the cylinder through ports about its periphery and passes through the orifice into the discharge chamber. As pressure builds up in this chamber, the diaphragm is forced against the spring compressing it. The valve stem and piston follow the diaphragm and the poppet and seat approximate each other to decrease the flow of steam so that a further increase of pressure in the discharge chamber is prevented. The force required

SAFETY POP VALVE

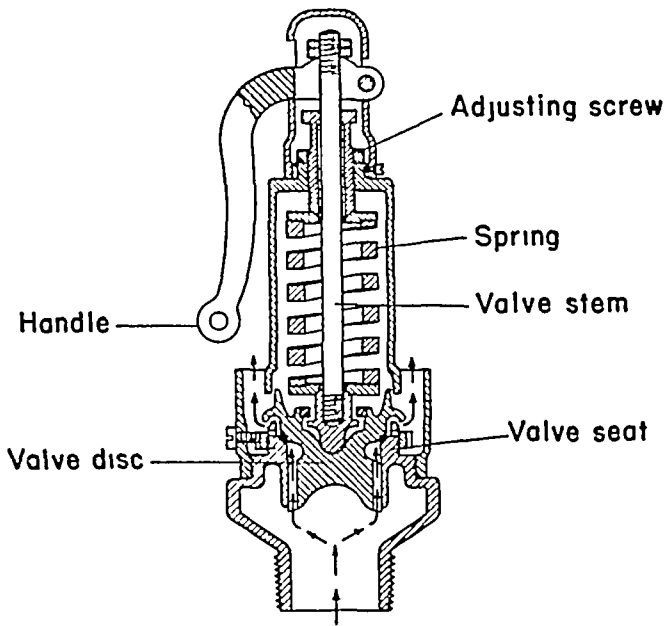


FIGURE 252

to close the valve is supplied chiefly by the steam pressure in the supply line leaking past the loosely fitted piston to aid the light spring behind it to close the valve. Dirt may cause the piston to stick and is the chief cause of failure of this type of valve. To protect against this, a strainer is fitted about the cylinder parts. This can be cleaned by loosening the cap screws and removing the end of the valve. Leakage of steam from the valve indicates failure of the diaphragm. This can be replaced readily.

After passing through the pressure-reducing valve, the steam is turned into the jacket surrounding the sterilizing chamber. Air and condensate which accumulate in this jacket are discharged from the sterilizer through a steam trap, figure 246, which must be connected to an open funnel so that the air and condensate are discharged to the atmosphere. In many hospitals, the steam return trap is connected to the return line to the boiler in order to conserve the small amount of condensate. This is not good sterilizing practice because back

pressure in a steam return line, due to faulty operation of other steam equipment, either floods the sterilizer jacket with water or prevents the discharge of air from the jacket, so that uniform conditions cannot be established in the sterilizer. In a large sterilizer, this may result in the lower half of the walls of the chamber being cold and wet. For optimum operation, the jacket trap should be connected as illustrated in figure 53.

The safety pop valve connected to the jacket is installed to relieve steam which is in excess of the pressure the sterilizer will withstand safely. When the pressure-reducing valve is functioning properly, the safety valve is inactive. Because of this, it often does not function for years on end and when the critical moment arrives for it to function, it sticks with disastrous results. Because the construction of safety valves is simple, they present no maintenance problems other than the daily chore of lifting the handle to make sure that the valve is free and that it functions easily.

A safety pop valve is quite like an ordinary valve with the exception that the valve disc is held against the seat by a spring instead of screw threads, figure 252, as is the case with an ordinary faucet or bellows in the case of the steam trap. Whenever the pressure of the steam against the disc exceeds the downward thrust of the spring, the disc leaves the seat and steam escapes.

When the safety valve pops continuously and the surgeons are annoyed by the hissing of the steam, do not tighten down on the safety valve to stop the noise but have the sterilizer repaired so that the safety valve is able to perform its normal function. Sterilizers have exploded because careless maintenance men screwed down on the safety valve as the easiest solution of a problem they did not understand.

In most sterilizers, the steam is led from

ACTION OF AIR EJECTOR

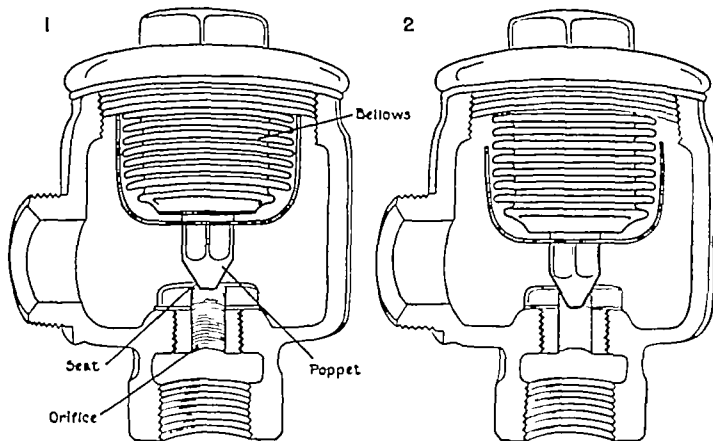


FIGURE 253

the jacket through a control valve into the chamber. In some sterilizers, this control valve is identical with those in figure 245. In others, an operating valve with multiple ports is provided to control simultaneously the admission of steam to the chamber and its discharge through the vent. Service on the latter type of valve is difficult and when such a valve leaks, a new one should be installed.

As the steam is admitted to the sterilizing chamber, the air and condensate are discharged through the chamber drain line. A screen is provided to catch detritus which might plug the drain line. This screen must be lifted from the exhaust port at weekly intervals and thoroughly cleansed before being replaced.

Little attention need be paid to thermometers located in the chamber drain line be-

cause they are designed to give foolproof service and unless their dials are broken, they need not be tampered with.

The air and condensate ejector is merely a sensitive steam trap. When cold the bellows contract and the poppet is lifted from the trap seat so that air and condensate can be discharged freely (figure 253, 1). After all the air and condensate are eliminated and steam fills the air and condensate line, the bellows are heated and they expand, forcing the poppet against the trap seat to prevent the escape of steam (figure 253, 2) and to permit pressure to be developed in the sterilizer. As soon as cold condensate or more air accumulates in the trap, the bellows cool and contract again. The air and condensate trap is the bit of equipment which must be checked carefully because failure of this trap is responsible for much

unsterile goods. The chief cause of failure is that dirt accumulates in the air and condensate discharge line or trap and occludes it, preventing the escape of air with the detrimental effect on sterilization outlined in Chapter VII. The fact that a sterilizer is new is no indication that this trap is functioning properly. In one hospital, faulty operation of a new sterilizer was reported. Investigation revealed that the insulating material which had been applied to the outside of the sterilizer had been stored temporarily in the chamber and when steam was admitted, odds and ends of insulating material got into the air and condensate line and plugged it so thoroughly that a new line had to be installed.

The patency of the chamber drain line must be tested periodically by pouring a quart of water down the exhaust port, except in sterilizers equipped for vacuum. If the water drains away freely, the drain line is free of dirt and the air and condensate ejector opens properly. If water does not run through the discharge line freely, the cover of the trap should be removed and the bellows taken out. Any dirt which has accumulated will usually be obvious because it customarily collects in the body of the trap. If no dirt is present, more water should be poured into the exhaust port. If it does not run into the body of the trap, the discharge line is occluded and must be removed for cleansing. In sterilizers equipped for vacuum, a check valve is provided in the air and condensate line to close it when the vacuum is drawn, figure 58, 1. This valve prevents the use of the water test described.

The gages on dressing sterilizers require adjustment occasionally. Although this adjustment is relatively unimportant from the point of view of sterilization, it does affect the operation of the sterilizer in that an accurate indication of atmospheric pressure

within the chamber is necessary to indicate when the door can be opened safely. Adjusting the needle to 0 accurately is easily done by unscrewing and removing the dial, figure 254, 2, and inserting a screw driver into the slot in the center of the needle, figure 254, 3. While the needle is pinned against the dial to hold it stationary, the screw driver is turned in the direction necessary to make the point of the arrow indicate 0, figure 254, 4. Several trials may be necessary to obtain the proper adjustment. The dial is then replaced, figure 254, 5.

The doors of steam sterilizers present many problems which can be avoided by proper operation and maintenance. Doors are the most important mechanical part because they withstand high pressure when the sterilizer is in use. The door of the ordinary cylindrical sterilizer, 40 cm in diameter, is subject to an outward pressure of 910 Kg. It is obvious that proper locking is essential for safety. Doors are made steam tight by a rubber gasket set in a groove in the head ring of the sterilizer. Only sufficient pressure against the gasket is required to prevent the leakage of steam. Greater pressure causes deterioration and early wear of the gasket. The majority of sterilizer attendants close the sterilizer door and screw up the hand wheel as tightly as possible before they turn on the steam. The proper technic calls for closing the door, throwing the locking bars, and turning the hand wheel until resistance is felt. The steam is then turned on and the sterilizer attendant stands by as pressure is built up in the chamber. As soon as steam leaks out between the gasket and the door, the hand wheel is turned up enough to stop the leak. Pressure may build up again to the leaking point and the hand wheel is turned up a second time. This is repeated until the door is leakproof when the maximum pressure has been developed in the chamber. In this

ADJUSTING GAGE NEEDLE

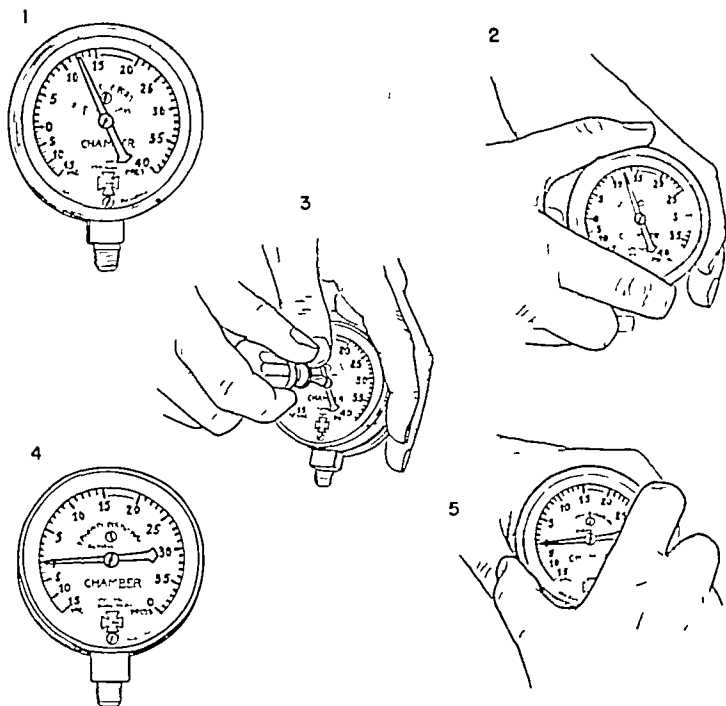


FIGURE 254

way the unnecessary pressure and early destruction of the gasket caused by the usual technic is avoided

Another point in the maintenance of gaskets is to be certain that loose ends of twine or cloth safety pins, and wire do not protrude beyond the edge of the door when it is closed to get caught between the door

and the gasket. Such foreign bodies cut the gaskets and begin minute leaks which cause early deterioration

There are two types of gaskets in common use — the formed gasket and the continuous length type. The chief points to be observed in replacing a formed gasket are to make certain that the groove is thoroughly

FITTING HEAD RING GASKET

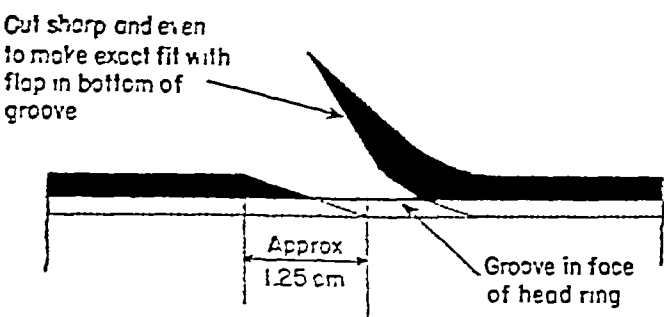


FIGURE 255

cleansed and that bits of old gasket are scraped away. New gaskets are usually apparently too long to fit the groove. The excess material must be fitted uniformly into the groove. This is done most easily by marking diametrically opposite points on the gasket and inserting these points into the top and bottom of the groove. The halves of the gasket are then fitted as evenly as possible into the groove. Care must be taken not to twist the gasket and to fit it smoothly. The area of the door which normally impinges on the gasket must be carefully inspected and any irregularity must be removed with emery paper so that the new gasket is not pitted by dirt or bits of old gasket which have adhered to the door. A small amount of powdered graphite or talcum powder is applied to the door before it is closed against the gasket. If the gasket is supplied in continuous lengths, it is a little more difficult to insert because it must be cut just long enough to fit well. The old gasket is removed and the door is cleaned as mentioned previously. One end of the continuous gasket is then beveled, figure 255, so that the bevel faces the plane of the door. The gasket is pressed into the groove carefully for about 30 cm. Thirty cm. further along about 10 cm. of gasket are inserted into the groove, leaving a small hump of gasket protruding from the groove. This loop is then carefully forced into place. In this way, the gasket is inserted under com-

pression rather than tension and will have longer life. This maneuver is repeated until the starting point has been reached. The gasket is measured accurately and cut to fit the beveled end which was initially inserted into the groove.

The hinge, door locking mechanism, and the center stud of sterilizers require periodic lubrication with graphite suspended in oil. Proper lubrication not only makes the parts work more easily but prolongs their life.

A check list for the proper maintenance of one type of steam heated dressing sterilizer follows. Similar check lists, specifically describing the maintenance of each sterilizer and suitably framed for mounting near the sterilizer should be furnished by manufacturers.

SERVICE CHECK LIST LARGE RECTANGULAR STERILIZER

- 1 Inspect head ring gasket.
- 2 Inspect door locking mechanism.
- 3 Oil hinges, thrust bearing, locking plate, and threads of center stud.
- 4 Adjust pressure gages to register zero when sterilizer is under no pressure.
- 5 Pour one gallon of water down air exhaust line. If there is an obstruction, clean out line or replace bellows in trap.
- 6 Fill rim of head ring with water. If it does not drain promptly, clean out drain line.
7. Turn steam into jacket; check operation of the trap draining air and condensate from jacket. Passage of air should be audible and condensate visible. If neither air nor water flows from trap, replace bellows.
- 8 Check door gasket with full head of steam. There should be no leakage.
9. Inspect valves and adjust or repack stem glands to prevent leakage when valve handle is being turned — steam supply valve — steam valve to chamber — vent valve.
- 10 Inspect safety pop valve, blow off valve with sterilizer under full pressure.

- 11 Pressure-reducing valve — adjust to maintain a temperature of 121°C in the exhaust line. The jacket pressure must not exceed 875 mm. Hg

INSTRUMENT WASHER STERILIZER

Instrument washer sterilizers, figure 109, present problems common to both the pressure sterilizer and the nonpressure sterilizers. Because water softeners are used routinely along with the detergent, scale formation does not occur. The only factor which must be emphasized is that the ejector, a trap similar to figure 253, becomes fouled with bits of rubber goods or string more easily than the air and condensate ejector in the dressing sterilizer. When this occurs, the pop valves blow frequently because air is being vented through them and instruments are likely to be dirty after their removal from the sterilizer because protein scums, alkali earth soaps, and grease did not escape through the ejector. It is a simple matter to unscrew the cap and clean the discharge trap.

WATER STERILIZERS

The chief item in the maintenance of water sterilizers, other than the routine inspection and tightening of valves, is to change the filters, figure 220, whenever they become plugged with sediment. The amount of sediment in the water supply determines how frequently such changes are necessary.

In hard water areas, lime salts are deposited as scale on the heating surfaces. In steam heated water sterilizers, the steam coil may have to be removed several times yearly and the scale scraped off. Gage glasses may become coated on the inside with lime salts so that they do not function properly. Gage glasses can be removed and cleaned. Before removing them, be certain that a complete set of new gaskets is on

hand so that the glass can be reinstalled properly.

Air filters on modern water sterilizers almost never need attention. As long as the water flows freely from the draw off faucet, the air filters are not plugged. When the flow diminishes shortly after the faucet has been turned on, it is evidence that the air filter is plugged with dust and requires replacement.

STILLS

The proper function of stills depends upon keeping the generator free from residual solids and the heating surfaces free from lime salts. The need for cleansing is indicated by decreased output or, better, on the basis of experience with the particular still. In hospitals where much distilled water is used, daily or weekly cleaning may be necessary. In others where little water is used, monthly cleaning may suffice. In areas where hard water is not a problem, stills can be run indefinitely without any cleaning whatsoever. Only the generator of the still need be cleaned. The condensers should never be touched.

Decreased output of distillate from a still heated by steam may be due to faulty trap operation or back pressure in the steam return line. To insure satisfactory distillate, the steam and water pressures must be maintained at steady levels. The pressure-reducing valves installed for the purpose should be checked periodically. When stills function properly, storage tanks need not be cleaned. The only other maintenance item is the inspection of the valve stem glands. This is particularly important because stills may be located where drip from these glands can be annoying.

ELECTRICALLY HEATED EQUIPMENT

Electrically heated equipment calls for a minimum of service once a suitable installa-

tion has been made. Most difficulties arise from improper installation. Here, the chief fault is the careless matching of the voltage of the heating coils with that of the power outlet so that excess voltage causes early deterioration of the heating coils or low voltage causes provokingly slow heating. False economy in selecting inferior electrical control equipment or eliminating essential safety devices, such as low water cut-offs, for the sake of saving a few dollars is the chief cause of excess service. Unnecessary tampering with electrical equipment is another source of maintenance costs. Routine maintenance of such equipment is limited to cleaning of the heat exchange surfaces. The penalty for neglect is slow heating and ultimately burning out of the heating elements.

GAS FIRED EQUIPMENT

Gas fired equipment presents a problem

in routine maintenance because gas burners must be cleaned and the holes kept patent. The flame must be checked for proper combustion periodically. A good gas flame is one cm. high and is blue with an orange tip. When the flame is too small, the sterilizer heats slowly. When the gas mixture is bad, irritating odors result. Once properly adjusted, periodic cleaning of the burner and mixing chamber must be enforced. At each cleaning, the flame should be inspected and adjusted if it is not burning properly. Besides the safety devices essential to proper combustion, gas fired equipment must be protected by automatic pressure regulators and low water shut off valves to make its use safe and to avoid excessive replacement cost. This equipment requires little maintenance except for the low water shut off which may become fouled with scale. This device must be checked every time the boiler is cleaned.

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